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Mr. Theo. D. Rand, Chairman; Prof. Arthur Beardsley, C.E., Ph.D., Mr. James Christie, Dr. H. W. Jayne, Prof. Coleman Sellers, E.D., Committee on Publications, with the Assistance of Dr. Wm. H. Wahl, Secretary of the Institute.

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MR. JOHN BIRKINBINE, President, in the chair.

THE SMOKE NUISANCE AND ITS REGULATION, WITH ESPECIAL REFERENCE TO THE CONDITION PREVAILING IN PHILADELPHIA—IMPROVED FURNACES AND MECHANICAL STOKERS.

THE COXE AUTOMATIC STOKER.*

MR. MATTHEW C. JENKINS [New York]:—I take pleasure in describing to you to-night the automatic stoker invented by the late Eckley B. Coxe, of Drifton, Pa.

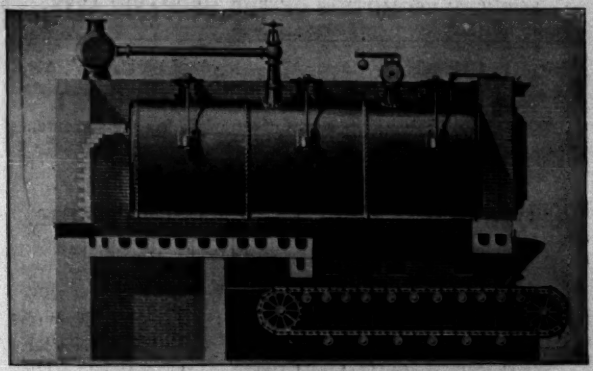
After a series of careful experiments carried on at Drifton, Mr. Coxe decided that for the proper, and at the same time the most economical, combustion of coal, the following conditions were necessary:

* Manufactured by the Coxe Iron Manufacturing Company, Drifton, Pa., and New York.

(1) To ignite the coal and burn it without mixing it with fresh fuel; that is, that fresh fuel should not be commingled with the already partially consumed coal.

(2) To have the furnace so arranged that the combustion should be continuous and uniform; that is to say, when the furnace was in use the condition of the fire would be practically the same at any hour of any day of any week of the year.

(3) To make the work of firing as easy as possible, so that a minimum number of firemen would be employed, and that the whole operation of the furnace would be controlled by an



Coxe mechanical stoking furnace applied to return tubular boiler.

intelligent man who would have more use for his brains than for his muscles.

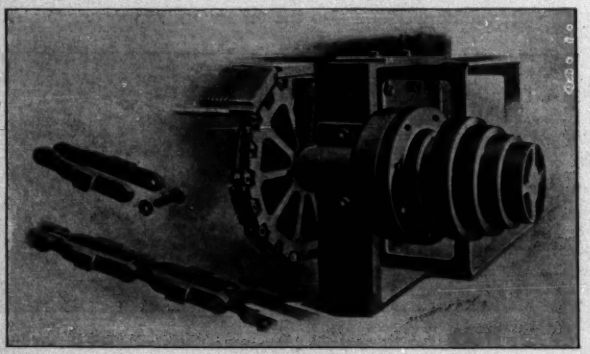
The Coxe automatic stoker was designed to comply with these conditions. It is an endless travelling grate, as shown in accompanying cuts, which receives the fuel at one end, burns it as it moves slowly along, and deposits the ashes at the other end. It was designed originally to burn the smallest sizes of anthracite coal, but handles bituminous as well and with an entire absence of smoke.

To insure complete combustion, and at the same time leave a minimum of free oxygen in the chimney gases, the

fuel, in passing the working length of the grate, is subjected to varying pressures of air. In other words, as the amount of carbon in the bed of fuel diminishes, the amount of air supplied is proportionately diminished to the rear, and thus an excess of air is excluded, and as nearly theoretical combustion as it is possible to obtain by any known means is reached.

One of the most important features of Mr. Coxe's invention is the variable air supply, which I will now explain, with the aid of accompanying illustrations.

All the air that enters the fire is conducted into the largest



Detail of chain, showing sprocket and reducing mechanism (Coxe mechanical stoking furnace).

chamber at the center of the frame, and the only air that can enter the adjacent chambers must pass through dampers in the partitions separating these chambers, which are closed at the bottom so that the supply can be regulated to suit existing conditions. In practice, the maximum amount of air is supplied at the center, and this is diminished to a minimum at each end; the dampers being regulated so that the pressure is diminished in each succeeding chamber.

The depth of the bed of fuel is increased or diminished by a gate in the hopper, that can be raised or lowered, as found

necessary. This fuel, on arriving on the grate, is given just sufficient air to ignite it slowly; and, as the ignited coal passes over the succeeding compartments where the air pressure is at the maximum, burns briskly. But when it has lost part of its carbon, it passes over the compartments where the air pressure is again diminished and better suited to the thinner layer of partly consumed coal. The bed continues to diminish in carbon and to be subjected to less air, until finally the hot ashes are cooled off by a very gentle current of air, and are then dumped into the ash-pit at rear end of furnace.

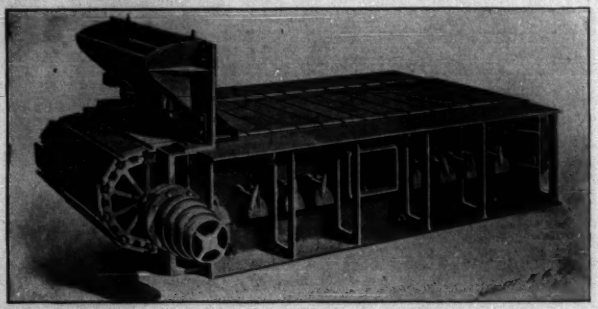
The furnace proper is composed of two side frames, which support the hopper and also the brickwork supporting boiler.

Details showing construction of grate-bars (Coxe mechanical stoking furnace).

They also carry four sprocket wheels, two front and two rear, over which run the chains to which the bar bearers (shown in next view) are bolted. The rollers shown both at top and bottom of frames carry the upper working and the lower returning runs of the grate.

The grate proper is formed of two parts—the "grate keys," shown detached and in place, and the "bar bearers." These latter are T-shaped, consisting of a vertical rib and a horizontal plate, and are cast the width of the grate. The horizontal plate is perforated with a number of cone-shaped holes, wider at the bottom than at the top, to admit of the free passage of the air, and have, on their upper surface, a dovetailed rib. At

each end is a lug, which fits in between the links of the chain, and is securely fastened to it by bolts. The upper part of the grate bed consists of the sectional bars, called "grate keys," which are 7¾ inches long by ⅝ of an inch wide, and are provided with projections which give an air space of about ¼ of an inch between each pair of these keys. At each end of the dovetailed rib, which is cast on the bar bearer, is a slot, dovetailed at the bottom, which will allow the lower part of the keys to drop into position on the bar bearer. The key is then moved laterally toward the center of the bar bearer and another is dropped into the slot and moved along, until the whole carrying bar is filled, with the exception of spaces occu-



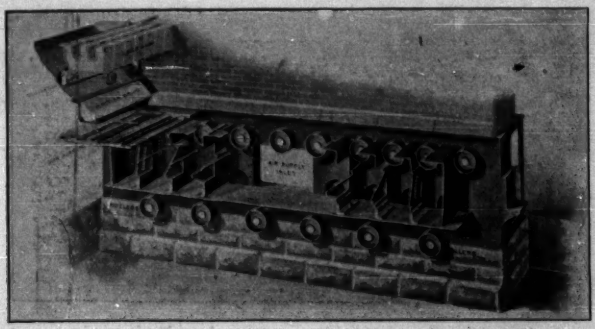
Perspective view of grate (Coxe mechanical stoking furnace).

pied by the slots at the ends. To prevent the keys from dropping off, dovetailed pieces, made of cast iron, which fill up the openings so as to make the dovetailed rib continuous, are inserted, and the keys are separated so as to be distributed uniformly through the whole length of the bar bearer, which they fill loosely. Then, as there is no push toward the left hand more than toward the right, and since it requires considerable force to move those on the extreme right hand over to the left, or *vice versa*, there is no tendency for them to drop off. This method of fastening the keys is very simple and perfectly effective.

To remove an imperfect key, a blow with a hammer on the thin part will allow the broken piece to be removed and a new one to be substituted at the end, the one left being moved up to fill the space occupied by the discarded key. The replacing of grate keys does not interfere in any way with the continuous operation of a power plant.

The chains which carry these built-up grate bars are made from drop-forged steel links, all the holes in which are drilled to insure accuracy; and the pins with which these links are riveted are made from cold-drawn steel, so that where strength is essential it is secured absolutely.

It will be obvious that by the slow motion of the traveling



Detail of air pans, etc. (Coxe mechanical stoking furnace).

grate, from 3 to 6 feet an hour, the tendency to get out of order is reduced to a minimum, and that any little unexpected hitch can be attended to and rectified without the slightest interruption of work. The time of exposure of each section while out of use is so long, that needed attention can be given in even a leisurely manner.

The movement of grate is hardly perceptible to the eye, to insure which we use a reducing mechanism, shown in cut, which is a series of differential gears inclosed in a cast-iron case and constantly running in oil, the details of which need not be explained.

The Coxe Stoker can be applied to any of the modern types of boilers. It comes in widths of from 3 to 10 feet, according to the output of the boiler. Another feature is that a plant equipped with the stoker is not necessarily tied down to any one kind of fuel, as the same machine will burn both anthracite and bituminous coal, and the latter, as already stated, without smoke; or mixed coal can be used. This is, of course, a point worthy of consideration, as in case of inability to obtain either kind of coal, through a strike or other cause, a change can be readily made without trouble.

So much for the description; now for the reasons why the Coxe automatic mechanical stoking furnace is a smokeless one. We all know that with the ordinary method of hand-firing with bituminous coal, the smoke is produced only when fresh fuel is added, and not at all after the same is burning briskly; or, in other words, the sudden elimination of the volatile matter contained in the bituminous coal carries off with it a small quantity of solid carbon produced in the incipient distillation of the fuel, and which appears at the top of the chimney, as smoke.

In the Coxe furnace the fresh fuel is ignited very slowly, owing to the variable air supply, and yet, after it *is* thoroughly ignited and travels toward center of furnace, has ample *air to complete combustion*, as the following analyses of chimney gases will show.

Average of five samples taken during test:

	Per Cent.
Carbonic acid	16·22
Free oxygen	2·54
Carbonic oxide	Trace

THE HAWLEY DOWN-DRAFT FURNACE.*

Mr. W. F. Tatnall:—"The Hawley Down-Draft Furnace" consists of an upper, or water grate, carrying coking coal, and a lower, or common grate, upon which the coked coal is burned. The upper grate has a down draft, and the main part of the air supplied for combustion is passed downward

* Manufactured by the Hawley Down-Draft Furnace Co., Pittsburgh, Pa.

through the fuel upon it. No coal is ever fired directly upon the lower grate.

The coal burning on the upper grate is incandescent at the bottom, or against the tubes, forming the water grate, and black or "green" on the top. The ignition of the gases takes place in the bottom of the fuel on the upper grate, thus producing a high initial temperature, which is needed for a complete combustion.

The water grate consists of charcoal iron 2-inch pipes connected to 10-inch headers. The tubes are set on an incline, lengthwise of the boiler, sloping towards the front, while the headers are set transversely. The front header is connected to that part of the boiler containing the coldest water, while

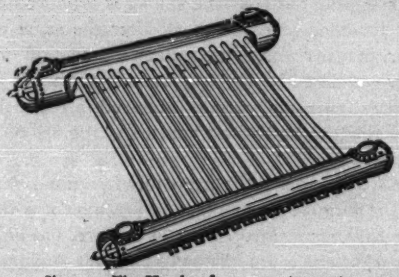


FIG. 1. The Hawley furnace water-grate.

the back header is connected to that part containing the hottest water, at or below the water line. In this way, through the heat given by the fires, a strong circulation of water is induced through the water grate bars, which protects them from burning. The furnace adds to the heating surface of the boiler. Each square foot of heating surface in the water grate has as much evaporating capacity as 5 square feet of the average heating surface of the boiler. The result of this increase in surface is felt in an increase in capacity, or in the total amount of water that may economically be evaporated with a given draft and fuel.

Brass plugs are provided in the front header, opposite each tube, and hand-holes are placed in each header. Through

these openings each tube and header may be examined and cleaned when needed. Blow-off pipes are connected to the headers for removing any collection of mud.

Principles of Combustion.—To secure the good combustion of a bituminous coal, it is necessary to have the following conditions:

(1) A high furnace temperature.

(2) A gradual and constant distillation of the volatile matter in the coal, and its thorough admixture with air under conditions favorable for the ignition of the gases.

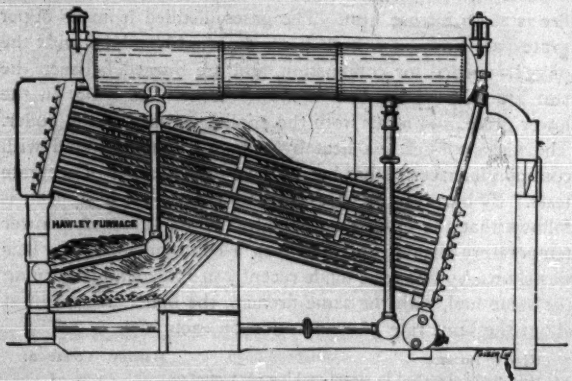


FIG. 2.—The Hawley furnace applied to horizontal water-tube boiler with sectional headers.

(3) The employment of no more air than is needed to thoroughly burn the fuel.

(4) The burning of the fuel in the furnace away from the cooling surface of the boiler or other user of heat.

To secure economy in the use of a fuel, it is necessary to not only have good combustion, as just noted, but also to—

(1) Prevent loss of heat by radiation, as far as is possible.

(2) To have the temperature of the gases discharged to the chimney reduced to as low a degree as is consistent with the draft required for combustion. This can only be done by hav-

ing clean absorbing surfaces of ample area, and a high initial temperature.

To keep the heat-absorbing surfaces clean, it is not only necessary that they should be free from scale or other non-conducting deposits, but also that the hot side of the surfaces should be free from accumulations of soot. This can be done by so burning the fuel as to produce smokelessness. It is, therefore, evident that all of the conditions just enumerated should hold, and that the formation of smoke should be prevented.

The Hawley furnace meets all of these requirements. Its fire is at an intense heat. The gases distilled from its upper grate pass away at a high heat, thoroughly mixed with the oxygen needed for combustion, and are burned between the two grates, over the bed of incandescent coke lying on the lower grate, and away from the cooling surface of the boiler. The furnace loses less heat by radiation than is found with common furnaces, as has been shown by a number of accurate tests. By burning the gases in the furnace, at a high heat, it follows that the gases passing into the stack are at a lower temperature than is obtained with a common furnace. This was shown by two tests made recently in Philadelphia burning the same fuel, with the same fireman, the boiler being run at about the same rate of evaporation on each trial.

Kind of furnace	Hawley.	Common.
Heat units absorbed in steam-making per pound of dry coal	11,225	9,767
Temperature of gases in chimney, degrees F.	458	663

Smokelessness.—The smokelessness of the Hawley furnace is well established. It practically makes no smoke because the combustion conditions are so nearly perfect that smoke is not formed. It is in no sense a smoke consumer. The city of Pittsburgh has had a salaried official observing the chimneys of its water-works boilers, equipped with Hawley furnaces, during the daytime, continuously for the past eighteen months. He finds that smoke is formed not to exceed 2 per cent. of the time, notwithstanding the fact that the fuel used is much more volatile than that sold in this market, and that the

boilers at times develop as much as 100 per cent. excess capacity. The results of these observations are public property, and may be seen at the office of the Director of Public Works. Such a record means smokelessness.

To further show that this furnace is smokeless, it may be stated to the Institute that it has been officially adopted by the cities of Chicago, Buffalo, Milwaukee, Toronto, Knoxville, Pittsburgh, St. Louis, New Orleans and Detroit for their

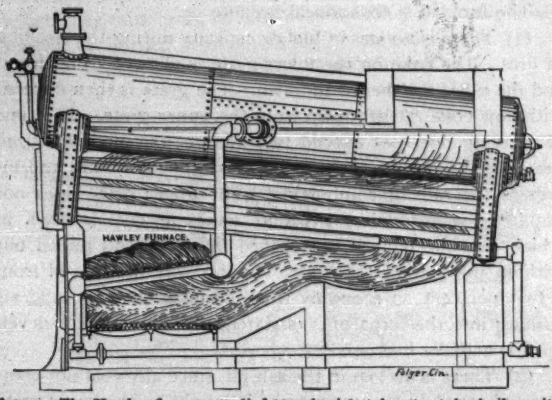


FIG. 3.—The Hawley furnace applied to a horizontal water-tube boiler with open headers.

municipal water or electric plants for the purpose of abating the smoke nuisance.

It may further be stated that the United States Government, which has heretofore burned high-priced grades of anthracite coals in order to avoid making smoke, has been enabled to save, in many instances, as much as 50 per cent. of its fuel costs, by burning bituminous coal in Hawley furnaces, at its plants in a number of important public buildings in Washington, Philadelphia, Baltimore, New York, Omaha and elsewhere.

The loss due to smoke from chimneys is not in itself expensive, but it is absolute proof of bad combustion, showing that

the volatile gases have not been ignited. The loss due to the passing away of distilled gases, rich in hydrogen, sometimes amounts to as much as 20 per cent. It may be said, however, that the absence of smoke is not a positive indication of economy. It is to be particularly noted that the Hawley furnace burns the rich volatile matter distilled from the coal, as this matter is liberated, and burns these gases without smoking.

The furnace is economical because—

(1) There is no loss in fuel or capacity during the cleaning of fires. The coke on the lower grate is allowed to burn out and the ashes are then withdrawn. The grate is then covered with new coke rattled down from the upper grate. The time of cleaning does not exceed two minutes for moderate-sized grates. The slicing of the upper grate opens its fire and increases the rate of combustion. The upper grate does not require cleaning unless a badly clinkering coal is used, in which case the clinker is loosened by a bar and pulled out without uncovering the grate. In this way the loss of from 3 to 5 per cent. in economy when cleaning fires, by cold air rushing into the furnace, is obviated, and the capacity developed is actually increased.

(2) There is no loss in the ash-pit, since any coal not completely burned on the upper grate is caught on the lower grate and consumed. The coke fire on the lower grate never clinkers with the coals obtained in this market.

(3) No cold air is allowed to come in contact with the heating surface of the boiler. The furnace temperature remains constant, and there is no change in the temperature of the gases in the tubes. This uniformity of expansion, and absence of sudden contractions, prolongs the life of the entire boiler setting as well as of the boiler.

(4) The hydrogen in the coal is worth 4·28 times as much as the carbon, pound for pound. The burning of hydrogen and other gases in the Hawley furnace is the chief cause of its efficiency.

(5) The circulation of water in the boiler is increased by the Hawley furnace. Freedom of circulation is needed not

only for life and durability, but is also important from an economical view.

(6) The practice of coaling heavily at long intervals, so commonly followed by ordinary firemen, with ordinary furnaces, is wasteful in fuel. With the Hawley furnace, on the contrary, it is of no disadvantage, as it is impossible for the gases from the coal to reach the cooling surface of the boiler until they have been ignited by the fires of the furnace, through which they must pass, as they have no other exit. No coal is wasted or burned with indifferent economy in the Hawley furnace so long as the grates are kept covered.

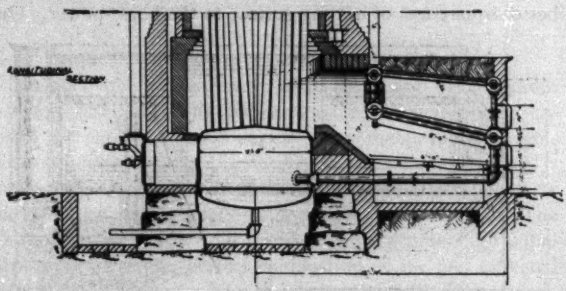


FIG. 4.—Hawley furnace applied to a vertical water-tube boiler.

(7) The coal used in banking a fire over night, for a plant run only during the daytime, is twice as great with a common as with a Hawley furnace. The time required for getting the fires in shape and for getting the boiler under full steam after banking, is least with the Hawley furnace.

(8) In the best modern plants equipped with common furnaces the evaporation per pound of bituminous coal is from 10 to 20 per cent. less than is readily obtained in the same installation after applying the Hawley furnaces. The difference between what is commonly obtained with such plants by the two kinds of furnaces, is shown by the following tests, made at a plant in this city, where the same fuel was burned under the same boiler, the fires being operated by skilful men.

and the trials made under the supervision of experts representing both the furnace company and the owner of the boiler:

Kind of grate	Common.	Hawley.
	Per Cent.	Per Cent.
Efficiency of boiler and furnace	63·9	79·6
Heat lost in chimney	20·8	17·3
Heat lost in imperfect combustion	5·7	0·3
Lost in ash and radiation	10·6	2·8
	Horse-Power.	Horse-Power.
Nominal rating of boiler	100	100
Boiler capacity developed	269	287

Capacity of Boiler.—The capacity of a boiler has been arbitrarily assumed by different builders to be a certain number of square feet of heating surface to the horse-power. One

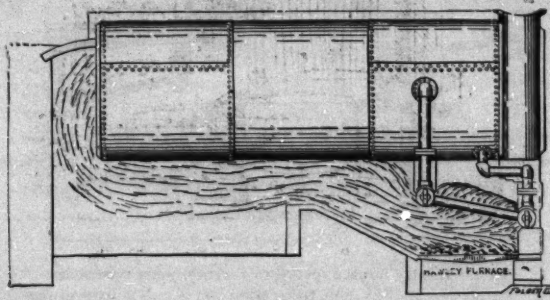


FIG. 5.—Hawley furnace applied to horizontal fire-tubular boiler.

builder of stationary boilers sells his product on 5 square feet to the horse-power, while another sells 15 square feet. A marine boiler develops a horse-power on from 2 to 4 square feet. Again, one builder will proportion his boiler to develop its nominal rating by burning 10 pounds of coal an hour to the square foot of grate area, while a marine boiler often burns from 40 to 50 pounds, and a locomotive boiler burns as high as 120 pounds.

Some Philadelphia manufacturers and steam users object to what they term forcing their boilers, on account of their inexperience with bituminous coal. They are familiar with anthracite coal, which cannot be burned economically at high

rates of combustion. If the rate of running a boiler to produce maximum economy has been determined for a particular boiler equipped with a common grate, the application of a Hawley furnace with the same boiler will permit 30 per cent. more capacity to be developed at the point of maximum fuel economy.

The Hawley furnace permits the economic capacity of a boiler to be raised without impairing the safety or life of the same, or its setting, about as follows, with proper draft conditions:

Nominal rating,	100 horse-power . . .	Relative efficiency . . .	80
Developed capacity,	125 " . . .	" " . . .	85
"	" 150 " . . .	" " . . .	90
"	" 175 " . . .	" " . . .	100
"	" 200 " . . .	" " . . .	90

In this table, it is shown that the point of maximum economy is at about 75 per cent. excess capacity. The so-called *forcing* of a boiler begins when the evaporative efficiency shows a decline. A stationary boiler thus operated, is not forced to anywhere near the capacity of a locomotive or marine boiler, and its safety or life is in no way imperiled. The Hawley furnace obtains this showing because of its high initial furnace temperature, perfect combustion of the fuel (effected in the furnace and away from the cooling surface of the boiler), and low temperature of gases in the chimney.

The engravings shown herewith exhibit respectively:

Fig. 1, the Hawley furnace water grate; *Fig. 2*, the Hawley furnace as applied to a horizontal water-tube boiler having sectional headers; *Fig. 3*, the Hawley furnace as applied to a horizontal water-tube boiler with open headers; *Fig. 4*, the Hawley furnace as applied to a vertical water-tube boiler; *Fig. 5*, the Hawley furnace as applied to a common horizontal fire-tubular boiler.

THE MURPHY AUTOMATIC SMOKELESS FURNACE.*

MR. O. D. COTTON [Detroit, Mich.]:—I need not tell you that the representatives of the "Murphy Automatic Smoke-

*Manufactured by the Murphy Iron Works, Detroit, Mich.

less Furnace" appreciate the kindly courtesy of an opportunity to present before this body the principles, construction and operation of the furnace.

One of the greatest difficulties in the way of the general successful introduction of this invention has been the fact that a furnace, although the basis of the successful operation of all steam plants, has not usually received the attention its importance justifies, I might properly say, demands. I find it a quite common practice by those who give attention to the

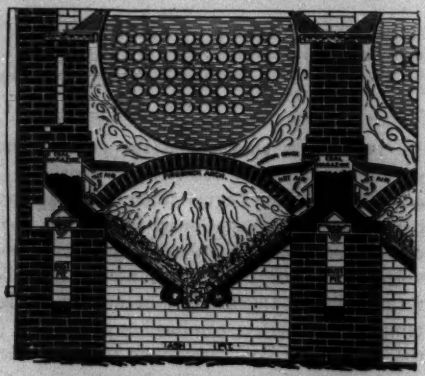


FIG. 1.—Cross-section showing Murphy automatic smokeless furnace applied to horizontal tubular boilers.

science of steam production and power to exercise much thought and care in the choice of both the engine and the boiler, but to give scarcely any attention to the furnace. In other words, the scientific and practical elements in the *application* of steam have overshadowed, and so prevented proper attention being given to, the method of burning the fuel—the most important factor in the cost of *steam production.*

The Murphy automatic furnace is unlike any other furnace, in that it is unique in nearly every feature necessary to its successful operation.

I will not here detail all the stages in the perfection of this

invention. It will suffice to say the most important stage was reached when Mr. Murphy conceived the idea of the mechanical feeding of the coal, coking it as it entered the fire-box, and burning the volatile combustible instantly and completely, thus doing away with smoke.

His furnace was then fed and cleaned mechanically, but by hand-power by use of a wrench. He soon found the average fireman could not be depended upon to stoke the coal, or to clean the fires with constant regularity, and then devised the automatic engine, gears and connections, substantially as now used, and the furnace then became a decided mechanical success. Commercial success, however, was yet to be attained. The high cost, as compared with the usual fronts and grates, was a serious, almost prohibitive difficulty, and he tried to cheapen cost by making a front feed on the same general lines, but after much time and not a little money had been expended, found there was not sufficient coking capacity to that style, nor enough economy to warrant the extra outlay for a mechanical furnace. He therefore fell back on the original type, and practical experience has shown that success required increased instead of decreased cost, because it was necessary to add to its cost in several details to make it capable of meeting all the requirements of the various and varying conditions of steam-power plants. Within the past two years a valuable improvement, which adds fully $50 per furnace to the manufacturing cost, has made it more completely automatic in the self-cleaning feature, has added to the capacity per square foot of grate, and also to the durability of those parts exposed to the fire. I am able now to present to you a mechanical automatic furnace that has been tried by every conceivable test of utility, and that has been perfected by the inventor after years of experience and suggestion from practical use, and which, we claim, is the best known smoke preventer under any and all conditions which obtain in steam-power plants. It is the only furnace which is automatically cleaned.

There are many forms of mechanical stokers, but there is but one *automatic* furnace.

The principle of its operation is immediate, rapid combustion by means of a coking and a coke-burning furnace, in which the volatile gases are instantly and continuously consumed in connection with the carbon or coke, producing complete combustion, high temperature and practical smokelessness.

By reference to *Fig. 1* the apparatus will be seen to consist of two boxes or coal magazines set in the wall on either side of the fire box. The bottom or base of these magazines is a heavy plate, made to serve also as a coking plate, over

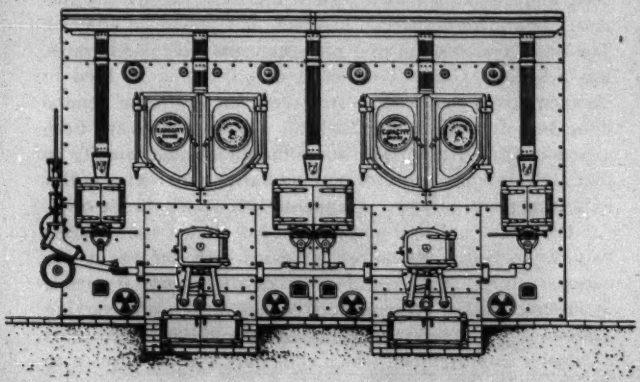


FIG. 2.—Horizontal tubular boiler (front view), equipped with Murphy automatic smokeless furnace.

which the coal is automatically stoked on to the grate. The inner side plate of this magazine has a foot extending inwardly toward the fire, and this forms the base on which a fire-brick arch rests. This foot is ribbed so as to leave a row of small openings the entire length of the arch. On top of this portion of the arch is constructed an air flue, which is supplied with air through flues from the front. The air passes through the flue registers, and through this flue, absorbing heat on its way, and passing down into the fire-box, through these openings at the base of the arch, insures a well-distributed supply of hot

air over and at the point where the volatile gas is being driven off the coal by this coking process.

Large coking capacity is essential to smokelessness, especially when strong duty is required. By this arrangement of coking surface we can coke thoroughly and burn without smoke all the coal the grate surface and draft will burn, the maximum being about 150 to 160 pounds per foot length of coking plate. Our largest size furnace will coke and burn without smoke fully a ton of soft coal per hour, which, we believe, is more than double the quantity any front feed or under feed mechanical or hand-fired style of furnace can coke thoroughly or burn without smoke.

This passage of air through these openings also serves to protect the iron from destructive heat. The operating parts are simple, strong mechanisms and are skilfully adapted to perform the required duty. The stoker boxes are simply inverted open iron boxes, with a rack under each end. The stoker shaft has a pinion geared to each rack, whereby the stoker boxes are worked back and forth on the coking plate, pushing the coal forward to the edge of the coking plate and on to the grates, the upper ends of which rest against the edge of the coking plate. The grates are in pairs, one bar of each pair being stationary, the lower end resting in a notch in the bearer in the center of the furnace and at the bottom of the *V*; the other bar of the pair, being free at the lower end and hinged to the upper end of the stationary bar, is rocked up and down by means of a rocker bar fitted into the lower end of the grate and which runs the entire length of the furnace, from front to rear, on a level with and near each side of the bearer. This constant rocking of every other bar keeps the fine ash sifted out from the bottom of the coals on the grate, thus maintaining a live, clean fire over the entire area of the grate surface, and also, by free draft of air, thoroughly protecting the grates from destructive heat. The clinker and other coarse refuse works its way down to the center of the *V*, where it glides off the end of the grates on to the clinker bar, which is a heavy, round, hollow cast iron bar, having wickers on its surface between the bearings, and, like the grates, supported

by the bearer and, by means of a ratchet gear, kept rotating, thus grinding up and depositing the clinker and coarse refuse in the ash-pit, in suitable condition for removal, either by hand or by mechanical conveyor. The stoker shaft, rocker bar and clinker bar are all operated by means of a flat bar attached to the outside of the front by lugs, which also serve as bearings. By reference to *Fig. 2*, it will be seen that this bar runs across the entire width of the furnace front, and connection with it is made by means of arms and detachable links. The

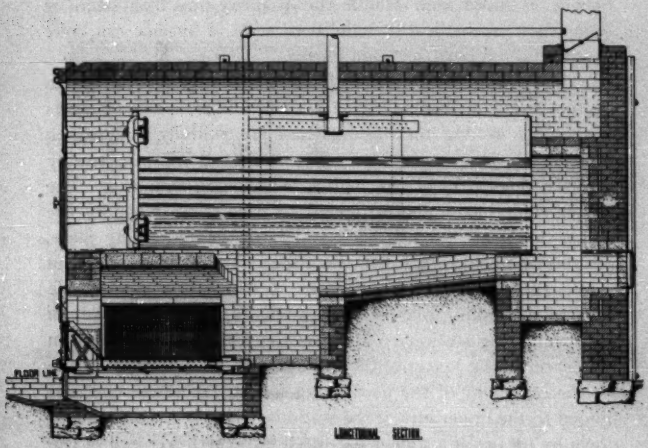


FIG. 3.—The Murphy automatic smokeless furnace, applied to a horizontal tubular boiler.

whole is operated by means of a small upright automatic engine, located on the corner of the boiler or battery setting, the power being transmitted to the automatic bar by means of worms and gears and a connecting bar, as shown. The automatic engine is either single or double, according to size of the battery, or number of furnaces to be operated, has a cylinder 3 inches in diameter, with a 5-inch stroke, and uses but ½ horse-power of steam per furnace operated.

The fire-box door affords ready access of view or of en-

trance to the interior of the furnace, while the detachable links enable the operator to operate any or all parts by hand with a wrench. You will note that each revolution of the driving gear slides the automatic bar back and forth, stokes a given quantity of coal on to the entire length of the grate surface on each side of the furnace, moves the movable grates up and down once and rotates the clinker bar. Thus, the coal is stoked into the furnace, the ash shaken from underneath the fire and the coarse refuse ground into the ash-pit with every turn of the driving gear, and these various operations so

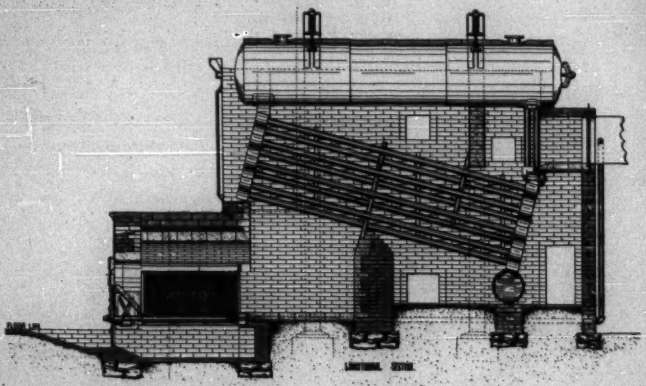


FIG. 4.—The Murphy automatic smokeless furnace, applied to a water tube boiler.

timed and adjusted as to feed the required amount of fuel and preserve a clean live fire, while the coal is slowly and constantly being coked as it enters the furnace, the resultant gas instantly and completely burned to carbonic acid. The coke, passing slowly down the incline of the grate as it is consumed, produces a clean white heat without smoke or soot, and, if the boilers have a proper amount of heating surface of approved form and are properly set to prevent undue radiation, the conditions of the highest practicable efficiency, both as to capacity and economy, should be realized.

In the earlier stages of our experience there was some difficulty in connection with use of low-grade "screenings," to keep the clinker from massing in the center of the furnace over the clinker bar, and thus clogging the furnace, and, in cases where the clinker was "runny" and strong duty required, the clinker bar became overheated and frequent renewal was required. In some such cases, the ratchet motion had to be abandoned and the clinker removed by hand, thus disturbing the evenness of the fire and admitting cold air to such an extent as to reduce the economy and cause more or less smoke at each recurring cleaning.

This difficulty has been satisfactorily overcome by means of our late improvements in the bearer and clinker bar, which, though retaining the original general form, are now so arranged as to admit of a current of cold air passing through the center of the clinker bar, and of a spray of exhaust steam playing on the outer surface of the clinker and grate bars under the bottom of the fire. By this arrangement of air and steam the bearer is protected against heating and consequent sagging, the clinker prevented from sticking to the grates, the clinker bar kept cool, and the action of the steam on the hot clinker cools and makes it brittle, so that it is readily ground through into the ash-pit, thus preventing the former difficulty of clogging, and so rendering the furnace as self-cleaning as it is self-feeding, relieving all the parts exposed to the heat from the former excessive wear, and also requiring less attention and less labor on the part of the fireman.

Another improvement, not shown on the views, is a slight change in the form of the grate bars, which prevents the sifting of the coal through the grates, which, in some cases, where slow coking or semi-bituminous coal is used, has been objectionable. The fire arch extends over the entire surface of the grate area, and is an essential factor in realizing the numerous advantages set forth in what has preceded.

Fig. 3 shows a longitudinal section of the furnace as applied to the ordinary horizontal fire-tube boiler.

Fig. 4 shows its application to the most usual form of water-tube boiler. These forms of application can be and are

varied indefinitely to suit special forms of boilers or special conditions of boiler-room space or other fixed requirements.

Fig. 5 shows one of the many forms of applying coal conveyor, bins, chutes, etc. In the plant shown in this view, the ash-pits are of "hopper" form, and discharge the ash in the ash conveyor in the basement.

Results.—The exact results in evaporation depend on so

FIG. 5.—Battery of boilers equipped with Murphy automatic smokeless boiler, with coal conveyors, etc.

many variable conditions in the various plants—the grade of coal, rate and regularity of duty required of boiler, condition of boiler, etc.—that record tests under the most favorable conditions are not fair comparisons. Experience, however, shows that from 10 to 13 pounds, and, in some specially favorable cases, a little over 13 pounds of water from and at 212° F.

per pound of combustible of good "screenings" or slack can be realized.

In comparisons with hand-firing we find a much greater saving shown in every-day work than is shown from record tests, because hand-firing on tests is usually by experts, or those who, by skill and extra care, realize from 10 to 25 per cent. better results than are obtained in regular work. Our experience, where we have displaced good hand-fired furnaces, shows savings of 20 per cent. or more in every instance, and in some cases has reached as high as 45 per cent., and in a few cases, where anthracite or expensive bituminous lump was used, the economy has reached 50 to 75 per cent. of former cost. To the advantage derived from such notable economy should be added those which are derived from its smokelessness, capacity, durability and general satisfactory service. It will meet sudden demands for increased steam with admirable promptness, because its unequaled coking capacity keeps the heating surface of boiler cleaner, and the fire can be "rushed" without opening the furnace or otherwise admitting cold or unnecessary excess of air, and without smoke.

[*To be concluded.*]

GEOGRAPHY OF PRECIOUS STONES.*

By George F. Kunz.

In speaking this evening on the geographical relations of precious stones, we may consider the subject in several aspects. Among these will be the geography of precious stones, with a brief description of some of the most famous gem regions; the influence of precious stones, both the search for them and the trade in them, on geographical exploration and discovery; the economic results of gem mining and gem traffic in the opening and settlement of regions otherwise remote, and the building up of cities and towns whose industries are the mining and the working of precious stones.

*A lecture delivered before the Franklin Institute, April 9, 1897. Copyrighted by George F. Kunz, 1897.

The geographical relations of precious stones are connected closely with the general topic of the history of commerce. I shall arrange the topics of this lecture, therefore, chiefly in their historical order, beginning with the earliest indications of commerce in gems, and passing down through classical and mediæval times to the conditions that we find to-day.

(1) Ancient and prehistoric time; in which all that we know is derived from the occurrence and use of precious stones in localities remote from their natural sources, or from very ancient traditions.

(2) Classical and mediæval time; embracing particularly the period of the Roman Empire and the centuries that follow, down to a recent date. Here our guides are literature, history proper, and the objects themselves in the great authentic collections of Europe.

(3) The modern world, with its immense developments of commercial, scientific and industrial progress, leading to new methods and new conditions in the procuring, working and transportation of precious stones and gems.

Beginning with a period before the existence of definite historical records, our first indications of the use of precious stones are found in Egypt and Assyria—in the latter at a period well established at about 4000 B. C.

A brief note on the forms into which gems have been cut in the various times may not be out of place here.

Precious stones in their natural state display but few of the beautiful qualities that we are wont to associate with them. These "crystallized flowers," as I have often heard our own Henry Ward Beecher call them, are frequently water-worn pebbles, roughened by attrition during years of wandering in the beds of streams and rivers; or, when found intact in their rocky homes, are often obscured by flaws and intruding matter which hide their beauty.

The earliest known gems were used as seals, either cylindrical, conoid, hemispherical or scarabæoid in form. The cylinder is believed to have been suggested by the joint of the bamboo, or the central whorl of a conch shell from which they

were first made. The conoid was a gradual evolution from the cone, then the hemispherical; then the scarabæoid, from the Egyptian scarabeus, or beetle, the symbol of immortality; then engraved gems. All of these seal gems were drilled; and about the beginning of our era, ring-forms, with the seal or subject on it, were made out of one piece of stone.

Such high artistic ideals as are portrayed on the gems from the sixth century B. C. to the fourth century A. D. have never been rivalled in any period of history.

Until the fourteenth century, all gems were either cut *en cabochon*, that is convex on one side like a carbuncle, or in the form of beads drilled from both sides in so rude a manner that the two perforations met very imperfectly. Then we have also the beads and facetted bead jewels of the East, brought into Europe by early commerce and by the movement of the Crusades, and the polished octahedral diamonds of the fifteenth century. Some of the finest gems in the crowns of Austria, Germany and Russia are sapphires and emeralds, that have been pierced partly or entirely, having served as pendants or as beads in Oriental necklaces centuries before. Rarely, if ever, have these ancient gems the perfection or beauty of color such as are demanded by the modern gem lovers. Finally, in the sixteenth and seventeenth centuries, we meet the facetted brilliant-cut stone, before whose clear light the superstitions of the centuries seem to fade away.

For a long time, it was supposed that the emeralds found in ancient Persian and Egyptian tombs and in the *débris* of the Alexandrian coast had come from the Ural Mountains—the great Russian locality of Takowaja,—but recent microscopical investigation by Schneider, of Dresden, has shown that they are from Jebel Zabarah, in Upper Egypt, where M. Caillaud, in 1830, discovered and reopened the ancient mines abandoned and forgotten for twenty centuries. These Zabarah emeralds were thus traded to the Orient, with garnets and turquoises from the Peninsula of Sinai, in return for the lapis lazuli of Media; and all the ancient lapis lazuli was from this source. It then was carved into the various forms of Osirids, scarabei, hawks and other objects so familiar in Egyptian art,

some found by De Morgan, in the tombs of the twelfth dynasty, 2400 B. C.; and all the emeralds used by the Tyrians, Etruscans and Romans were evidently Egyptian.

In the twenty-seventh and twenty-eighth chapters of the book of Ezekiel, we have a most vivid and detailed description of the world-wide commercial intercourse of ancient Tyre; and it is interesting to note how prominently precious stones are mentioned in this account. The Phœnicians were unquestionably the great receivers and distributers of these valuable objects from a very early day through many centuries.

Another, and one of the earliest and most interesting of the lines of prehistoric trade, is that of the amber commerce, from the Baltic to the Mediterranean, across Central Europe, and down the Rhone Valley to Marseilles, the ancient Greek Massilia. The amber, found in the Kertsch tombs in Southern Russia, Helm and Conwentz identify as of Baltic origin. It belongs to about the same age as that found in the Tyrian tombs, that is, 500 B. C. to 300 A. D. The myths, traditions and fancies that gathered about this singular and beautiful substance, its strange occurrence washed up by the waves on the shore of the Baltic, and its remarkable electrical properties, all combined to render it from very early times an object of mysterious interest and value, and to endow it with especial powers of supposed importance to health, safety and fortune. But amber is not out of, or given up by, the sea itself, or the tears of sorrowing seabirds, as stated by the poet, but is washed out of the tertiary coast deposits and sea-bottom, disturbed by the sea; and at present is not only dredged for by hand and steam dredges, but actually extensively mined from the same tertiary deposits miles inland.

Many of the most precious stones, however, such as the ruby and sapphire, have from the earliest ages been brought from the East Indies; and it is interesting to trace some of the stages in the history of trade with those rich regions of the earth. The first routes of commerce from the far East seem to have been two—one by the Persian Gulf and the Euphrates to Babylonia and Assyria, and thence by caravan through Damascus to Tyre and Sidon; the other by the

Red Sea and Suez to Egypt. Sir George Birdwood furnishes positive evidence that the Phœnicians visited India 2200 B. C.

The great early civilizations of Phœnicia, Mesopotamia and the Nile Valley, doubtless, thus became familiar with the gem treasures of Eastern Asia. Then came the opening of the Mediterranean, with first "the great Sidon," and later Tyre, as the starting points of commerce, exploration and colonial settlement among the islands and on the shores of what, to the Asiatic peoples, was the great western sea. As the Greek islands and their colonies developed, however, the Phœnicians confined themselves more to Africa and Spain. Gades, Tartessus and Carthage were their great colonies and trading ports, and their adventurous sailors passed on through the Straits of Gibraltar and northward to the British Isles for tin, and they very possibly obtained also the pearls of the Scotch rivers, as well as the Baltic amber; as centuries later, Suetonius tells us that Cæsar sent an expedition to obtain pearls for a buckler for the statue of Venus Genetrix. We even find indications of their having enslaved natives of the Spanish peninsula to work the mines of that region for gold, silver, topaz and other precious materials—even as the Spaniards of later ages dealt with the natives of the New World. It is to this date that we may attribute the Guarrazar treasure of the Spanish kings, now in the Cluny Museum in Paris.

The campaigns of Alexander had carried Greek influence and authority over all western Asia, reaching even to India itself, and had led to a widely increased intercourse. Alexander the Great, who lived to be only thirty-two years old, taught his merchants that their carrying capacity was increased one-fourth by using gold as a buying medium instead of silver; and precious stones were even a greater saving of camel power. In the bazaars of Alexandria, then as now, could be found the traders of India, Persia and Arabia bartering their treasured gems.

But Rome was destined to assume the leadership and to subject to herself all the resources and attainments of her early rivals. For the first time in history was there a great system of permanent and well-kept facilities for land travel and land

traffic. The great roads starting from the Forum reached out, in every direction, to the limits of the Empire. During the 500 years of Roman supremacy that followed the Phœnician sway, more gems were cut, mounted and worn than during any other early period; and at this time so abundant were engraved gems, that the outlines of the Roman Empire can be traced by the engraved gems alone, found in the tombs of its various dependencies. With the fall of the Empire, however, the Dark Ages came down like a cloud over Europe for 500 years; only among the Saracens and at Byzantium did any vestiges of the old civilizations remain; and in time the light of knowledge and progress was rekindled in Europe from these sources. The war and strife through the centuries of struggle between the Cross and the Crescent, beginning with the Crusades, ended only with the fall of the Eastern Empire.

To this period may probably be referred many of the finest jewels now found in the churches, collections and royal treasuries of Europe, especially the large peridots, some of them over an inch in diameter, such as those in the chapel of the Three Magi, at Cologne, which have long been believed to be emeralds, valued at $15,000,000, but in reality peridots, worth only $100,000. Their history and their source are unknown; but they are said to have been brought from Egypt centuries ago, whether as articles of commerce, as loot, or as mementoes of the Crusades, history fails to tell us.

The Crusades gave a mighty stimulus, by which Europe was awakened and brought into contact once more with the Orient. Venice and Genoa now became the carriers, first of pilgrims and war material, and then of a wider commerce, as intercourse and wealth increased. From this time and to this source may be traced many Oriental gems in Europe, and a new development of interest in them, as in many of the allied arts. Then followed the great period of mercantile prosperity for Venice and Genoa, which became the gem markets of the world, and founded stations and colonies around the eastern coasts of the Mediterranean, as the Phœnician cities had done so many centuries before. The Venetian fleet of 3,000 merchant ships brought the products of the East, and distributed

them over Europe, by way of the German cities of Augsburg and Nuremberg, where the great jewelers and silversmiths made world-famed products; and thence to interior Germany and the towns of the Hanseatic League; while the Rialto of Venice was the scene of many important gem sales.

With the advent of the "unspeakable Turk," Constantinople fell; and the wealth and treasure and learning of the Eastern Empire were scattered through Europe, to become the seeds of a revival of culture that broadened into the Renaissance. At the same time, the way to India and the far East was closed to the merchants and travellers of Europe; and hence new modes of access had to be sought by sea. With the voyages of Da Gama and Columbus, the newly-opened routes and the newly-discovered lands were claimed and appropriated by Spain and Portugal, while Venice and Genoa declined. Now began the wonderful period of Spanish and Portuguese development, colonizing and conquering in the Indies of the East and the West. In all this great activity, precious stones played a leading part. The search was evermore for

> "The wealth of Ormus and of Ind,
> Or where the gorgeous East, with richest hand,
> Showers on her kings barbaric pearl and gold."

Portugal founded her colony of Goa, and from that time controlled the diamond trade of India. In the next century the diamond fields were discovered in Brazil, which also belonged to Portugal; but ere long, as so often in history, bigotry and oppression threw away the prizes which nature had given and enterprise had developed. The persecution of the Jews in Portugal led to a transfer of the diamond-cutting industry to Holland, and Amsterdam has since then been the diamond-cutting center of the world. In Spanish America the native races and semi-civilized empires of Mexico and Peru were overthrown amid treachery and blood, and a tide of plundered wealth began to set eastward to fill the coffers of Spain. It is one of the most marked instances in human history of rapid changes—social, economic, political and racial—resulting from the greed and the search for precious metals and gems.

After the conquest of Mexico, Cortez sent back to Spain a number of articles taken from the treasures of the unfortunate Montezuma, among which were some works in emeralds of quaint and charming beauty.

A somewhat similar account might be given of the Spanish interest in the pearls found in the possession of the natives of the New World. They attracted the attention of Columbus himself, and aroused in his mind great anticipations of the wealth of the region in these precious objects.

We are not dependent, however, on the Spanish chronicles alone for our knowledge of pearls in the New World. The prehistoric races of America made great use of pearls, and possessed them in enormous quantities, some from the true pearl oysters of the Pacific Coast and Panama. But De Soto's pearls were undoubtedly from the fresh-water shells (Unios) that abound in such profusion in the streams of the Mississippi Valley, and are even now yielding beautiful and valuable pearls at various points, though rapidly threatened with extermination by reckless seekers. The finding of thousands of fresh-water pearls in a single mound in the Miami Valley by Prof. F. W. Putnam and Mr. Warren K. Moorehead, the latter find now in the Field Columbian Museum, gives one a faint idea of the great abundance of this regal treasure of the waters.

Having thus followed briefly the history of the principal routes by which the precious stones of the Orient were brought to Europe and distributed among the Western nations, it is worth while to turn to some of the present and probable future aspects of the same subject. One curious fact which meets us here is, that under new conditions the gem traffic from the far East to Europe is beginning to return to the earliest courses—first, by the Suez Canal and the Red Sea; and second, by railroad routes now proposed from the eastern end of the Mediterranean *via* Damascus to Persia, and thence to India. We will now turn to some of the localities of precious stones.

Originally, and for many centuries, the only source of diamonds was India, where they occur in river gravels in several districts of the central and southern part. The chief of

these was the region near Golconda, in the valley of the Kistna River. The phrase, "diamonds of Golconda," refers not to the actual mines, but to the town to which they were taken for sale. It was the great diamond market, the capital of the district, the Kimberley, as it were, of the day, but is now little more than an abandoned fort, the Indian mines being largely worked out.

In 1734, diamonds were found in Brazil; and for 120 years large quantities came from this source, chiefly from the province of Minas Geraes, near Diamantina. They occur much as in India, in river gravels and surface deposits, and in a conglomerate of quartz pebbles, called *cascalho*, derived from the consolidation of older gravels. After various attempts to work the beds profitably, by the Government and individuals, the firm of Hope & Co., Amsterdam bankers, undertook the whole management, assuming the national debt of Brazil and receiving the entire output at the rate of $9 per carat. This was about a century ago, and it resulted very successfully, and was the main cause of making Amsterdam the diamond market of the world. The persecution of the Jews in Portugal also led many of them to Holland who were diamond cutters, and this industry centered at Amsterdam, and gave it great commercial importance. Of late, Antwerp, London and Paris are overtaking it in this industry, Antwerp cutting one-quarter of the world's yield to-day.

Within the last thirty years the Brazilian mines have declined, and now furnish less than 5 per cent. of the world's supply ($150,000 annually). Future introduction of improved methods and modern machinery, instead of the rude slave labor before employed, may render these mines again important; but at present they are overshadowed and undersold by the great African diamond yield.

The African discoveries, which have revolutionized the diamond trade of the world in a few years, began in 1866, and have had several distinct stages of development. The first diamonds found occurred, like those of India and Brazil, in river gravels, chiefly along the valley of the Vaal River, from Potchefstrom to the Orange River, and somewhat on that

stream. These, known as the "river diggings," are now of but limited importance.

In 1871 were discovered the "dry diggings," in Griqualand West, between the Vaal and the Orange Free State. These consist of several small areas, only a few hundred yards across, grouped within an area of a few square miles, the erosion of which had supplied the "river diggings." But here the diamonds occur in place, in earthy beds of decomposed volcanic rock; the upper portion is soft and yellowish, known as the "yellow ground," but at some depth it becomes harder and changes to a blue-gray color—the "blue ground," "blue stuff" or "blue." These are all altered conditions of the hard igneous rock peridotyte, which is found unchanged at a depth of several hundred feet, containing diamonds in equal abundance. At the present depth of 1,200 feet, diamonds are as plenty as ever.

The commercial and industrial development of this region is simply marvelous. The city of Kimberley, with 55,000 inhabitants, and all modern appliances, has sprung up in a few years in the former desert; and the whole region is alive with modern activities. At first, the mines were worked as a host of separate small claims; but these were gradually united in a few large companies, and these, in 1889, were combined into the one immense corporation, known as the De Beers Consolidated Mining Company, which absolutely controls the diamond market of the world. Its capital is $19,000,000, and its market value in dollars $90,000,000. This gigantic scheme was planned and carried out principally by the genius and daring of one man, Mr. Cecil Rhodes, who became its chief director, ably seconded by his lieutenant, Mr. Gardner F. Williams, of California. Mr. Rhodes came to Cape Colony a lad, without wealth or influence; but in the diamond fields he rapidly developed both, and finally became the controlling head of the mining interest, then rose to prominence in the politics of Cape Colony, and became the organizer and head of the British South African Company. His great energy and ability, his prominence in recent aspects of South African politics, and his well-known ambitions regarding the extension and

unification of British interests and influence in that continent, all render him a conspicuous figure at the present time; but in justice to him let me say here that he is a creator, not a wrecker. When he prospered, everyone prospered.

The African mines have produced altogether about $350,000,000 worth of diamonds, which, when cut, are worth $700,000,000. This exceeds two-fold the value of all the diamonds previously known in the world. The Consolidated Company, which controls the whole of the district, limits the output, so as not to lower the price; and thus far all that have been produced have been taken up by the world. The trade is conducted by some 8,000 jewelers, carrying in stock about $350,000,000 worth, which is about one-third of the whole amount of diamonds known. Fully 30,000 people are employed in cutting and selling diamonds, and 10,000 in working the African mines.

Next after diamonds in actual value come rubies and sapphires, which are the red and blue varieties, respectively, of the mineral corundum. These have long been brought from the far East; and it is only of late years that some of these localities have been accessible to Europeans. The true rubies have come chiefly from Burma, Siam and Ceylon, and it is remarkable that two of these regions, as well as the African diamond fields, are now under the control of Great Britain, and the Siam ruby fields are really in English hands. England well protects the sources of gold and precious stones. The famous ruby mines of Burma were an incentive for England to conquer the Burmese kingdom in 1888. Two wars, costing $15,000,000, and the deposing of King Thebaw, who did not own the mythical dishes of rubies that were so famous, brought the mines into England's hands. The white-haired financiers who were clubbed from the offices of the Burma Ruby Mining Company, in their eagerness to obtain the stock which was subscribed for three times over, did not lose so much: it was then held at 300, now at 20, and has never paid a dividend. The much-prized pigeon's-blood rubies of Burma to-day command almost prohibitive figures in every land, are almost impossible to obtain, and they generally are old gems

sold by former owners. In Burma the climate is the greatest enemy of the European. Of fifty English officers who visited the mines, forty-eight had the local fever; the other two had had it before.

In Siam the gem-producing district lies in the interior, not very far from Bangkok. It produces many good rubies and sapphires; the rubies are generally darker in tone than the Burmese. The mines are worked by various persons and companies holding concessions from the Government. The gems are found in a layer of soft yellowish sand, at a depth of from a few inches to 20 feet. The methods of working are of the most primitive Oriental kind.

Ratnapura, the city of rubies, at the foot of Adam's Peak, Ceylon, at an altitude of 1,000 feet, is a great mining center. The most primitive mining has been carried on for ages past in that vicinity.

But the hopes entertained as to both Burma and Ceylon have hitherto been disappointed, nor does there appear any chance of future success, unless with improved methods of machine working. One who has been active in this gem-mining enterprise says: "What we want is an honest machine, one that will not only obtain for us the gemmiferous stuff, but that will securely guard it from the pickers and stealers until it can be raised to the surface and treated under close European supervision."

As a result of the work undertaken by European mechanical agency in Ceylon, the bazaars of Colombo were fuller than had ever been known before of gems of various kinds; yet only a few of these had passed through the hands of the companies working the mine. Thus, Kandy did not revolutionize into a South African regulated mining district.

[*To be concluded.*]

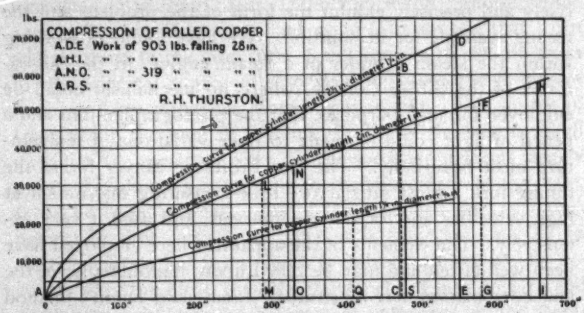
A PHOTOGRAPHIC IMPACT TESTING MACHINE FOR MEASURING THE VARYING INTENSITY OF AN IMPULSIVE FORCE.

By B. W. Dunn,
Lieut. Ordnance Department, U. S. Army.

DISCUSSION.

R. H. Thurston:—I have been much interested in this paper, not simply as relating to a somewhat novel phase of a subject which has been little discussed or worked up, but because many regard it—as, indeed, I do myself—as one likely to find valuable outcome in the art of determining the characteristics of the materials of construction. The wonderful success of Dr. Crehore and his coadjutors in the measurement of minute spaces traversed, and of variations of high velocities, has led us all to accept without prejudice any proposition looking to further development of similar methods or principles in any directions; and this is one of the evidently open fields for such further applications. The need of such processes of exact measurement was strongly brought to my own mind some years ago, when a controversy over the relative merits of heavy drop-hammers, and a dispute over a contract relating to them, was brought to me for settlement, if possible, by exact scientific methods of test of their efficiency. The attempt was then made to ascertain the work done, and to compare it with the power demanded, by crushing copper cylinders under the hammers and then comparing the effects with similar distortions produced in a compression-testing machine of the usual kind, measuring the weights required to produce measured quantities of distortion of crushing. While the work was useful in settling the question at issue, it brought very forcibly to mind the problem of securing a reliable measure of inertia effects and of their influence in modification of the results of the comparison between the static effects and the dynamic expenditures of work. The results of the tests thus made will be found described in Vol. III of my

"Materials of Engineering," Sec. 172, p. 281, with a plate presenting the curves derived. This plate is here reproduced with its scale reduced; but it is easily read and demands no remark in explanation. It was then stated in its accompanying text that "the effect of impact on the tough metals having no definite limit of elasticity is modified by the velocity of the striking mass, and by the inertia of the piece attacked, to an extent as yet not fully determined." It was concluded that the work of deformation increased, with soft and inelastic materials, with increasing velocity of striking. The contrary seemed to be the fact with, for example, irons and steels, in cases in which a definite elastic limit existed. In the figure,



the areas are obviously the measures of work done, and those cut off by full-line ordinates and by dotted lines, respectively, measure the work of the most and of the least efficient drop-hammers employed. The curves are apparently cubic parabolas.

The problem, of which the solution is here sought, is evidently, in fact, that of reducing inertia effects to quantities which, under the circumstances of the case in hand, may be neglected. Modern science and its methods of exact measurement are now supplying us with the means of solution, and the apparatus under discussion is an admirable illustration of such methods.

The paper before us gives a clue, at least, if not a com-

plete solution, of the problem, and permits comparison with far greater accuracy than ever before, I think perhaps with an accuracy which may be accepted as sensibly and almost physically perfect; and one of its most interesting results, seen in the figure comparing dynamic and static resistances (*Fig. 11*), is the proof that there exists a measurable difference between the deductions from the static and those from the dynamic system of test; while, nevertheless, this difference is not very important from the point of view of the designing engineer working any ordinary forms of structure or machinery.

The descriptions of the principles and methods described by the author of the paper are admirably rendered, and concisely and precisely exhibit the form of the problem and the means available for its solution. We have found in working within the steam cylinder of a steam engine, in the laboratories of the Sibley College, where no mechanism could be employed for such purposes, that the photographic film and a pencil of light could be made to trace variations of temperature most beautifully. The late Professor Mayer found the tuning fork a most satisfactory time-measuring instrument at high velocities and for minute intervals, and used it very extensively. The elements of the apparatus here employed have been well tested and may be relied upon, undoubtedly, in the new combination here illustrated. Lieutenant Dunn's method of measurement and scale making is extremely beautiful. The delicacy of the time-measurement system is something marvelous. In the distance-measurement, the apparatus has a theoretical perfection only modified, so far as I can see, by the inertia of the one material and inertia-laden element in the train—the mirror. It will be interesting to ascertain just how much error is introduced by this one moving solid body. If this error may be neglected, the system would seem to be practically perfect. The experiments of Mr. Hotchkiss, in the Department of Physics at Cornell University, in the use of an apparatus for the tracing, automatically and autographically, of the curves of fluctuation of the alternating electric current, indicate that, with a minute mirror, such as is easily made by the expert, a period of vibration, measured in thousandths of a

second, may be obtained, and the curves traced with practical exactness. With sufficient care in the production and attachment of a practically inertialess mirror, equivalent exactness of measurement should here be secured. For refined, and particularly for laboratory work, in the testing of the resistance of substances to impact compression, it would seem that this system should find practically useful application. The demand for more and more exact methods of experimental work in applied science and in engineering is constant, and is continually more and more imperative. Scientific research, in both pure and applied science, should here find valuable aid.

PROF. J. B. JOHNSON [St. Louis, Mo.]:—I have been much interested in reading Lieut. Dunn's paper on "Photographic Impact Testing Machines," and while I do not feel that I can add anything to the discussion, I will venture to call attention to the principal source of error in computing the impulsive force, or force of impact, from any such test. This source of error lies in the want of absolute rigidity of the base or anvil on which the specimen rests. If the specimen deforms largely under the blow, as compared to the movement of the base, then the error is small. But if the specimen does not thus deform or flow largely, as when it is subjected only to an elastic deformation from which it fully or almost wholly recovers after the blow, then the movement of ever so firm and rigid a base is likely to be large as compared to the (temporary) deformation of the specimen, in which case the computed force of impact, by this or any similar method, would be much greater than the actual force exerted. That is to say, this or any other method of computing the force of impact must rest upon the assumption that all (or some definite portion of) the energy of the falling weight passes into the specimen and spends itself in deforming it, either temporarily, or permanently, or both. This is the great unknown, and unknowable, function of the problem. Safety lies only in making the deformation of each and every blow very large as compared to the possible movement of the base under the blow. The failure to perceive this necessity is the fatal pitfall into which most experimenters with impact machines have fallen.

If the experiments made with Lieutenant Dunn's very ingenious machine be limited to some very malleable metal like copper, and to sizes and forces of blows such as to result in large deformations for each blow, and if the specimens be made to rest on very massive and rigid supports, as large blocks of steel, for instance, then the computed impulsive forces would be but slightly in excess of the actual forces which operated to produce such deformations.

For general purposes, however, in studying the resistance of brittle materials, like cast iron, for instance, to shocks or blows, this machine can have no important place. For such purposes a machine must be used such as will break the specimen at the first blow, and then indicate how much energy is left in the falling body (pendulum) after the specimen breaks. This, subtracted from the total energy in the moving body at the instant of impact, gives the energy required to break the specimen, but it gives no indication of the maximum impulsive force.

Such a machine has been designed, and is now in successful use by Mr. S. B. Russell, M. Am. Soc. C. E., of the waterworks department of the city of St. Louis. For some purposes, however, as in gunnery, it seems necessary to find a measure of the maximum impulsive force, and as this cannot be assumed to be the same as is required to produce a like deformation, statically, then some such machine as that designed by Lieutenant Dunn is necessary. He seems to have solved this problem very successfully, and deserves, and I trust will receive, the thanks of the engineering profession. It is the first successful effort of the kind which has come to the writer's attention.

Mr. George Gibbs:—From the hasty examination I have been able to give to Lieutenant Dunn's article, I should say that the author had developed the beginnings of what may prove an exceedingly valuable instrument of research to the physicist and engineer.

The engineering profession will certainly look forward with great interest to the development of a practical machine on these lines, and even if it is not possible to develop an instru-

ment which may be used in every-day commercial testing work, the results of the investigations with a laboratory machine would hardly fail to be of the greatest value to the profession.

The inadequacy of all the existing testing methods to give us knowledge of the effect of impact, has been apparent to all engineers having to deal with the testing of materials. In railway engineering, especially where the rolling stock and structures are subjected to the effect of impacts and rapidly alternating stresses, the lack of adequate means for the scientific investigation of a new material has been severely felt, and for this reason the introduction of new grades of material, or changes of proportions of structures, has been undertaken with the greatest caution. It will be seen that a more intimate knowledge of the maximum intensity of the stress developed by the blow might permit the quality of the material to be modified, with great advantage to the life of the structure.

I shall look forward with great interest to the development of Lieutenant Dunn's very beautiful machine, and only regret that I have not the opportunity to give the subject more careful consideration at this time.

I would suggest that Mr. Bond, of the Pratt & Whitney Company, would possibly be able to undertake the development of Lieutenant Dunn's machine, and if so, I know of no one more competent to produce the required results in accuracy of workmanship and refinement of design.

Prof. I. P. Church [Ithaca, N. Y.]:—Being somewhat belated in this matter, the writer has been unable to make more than a hasty perusal of Lieutenant Dunn's description of his impact machine and methods pursued therewith, but is much impressed with the wonderful precision and delicacy attained in the subdivision of time and with the care and pains taken in the reduction and interpretation of results as traced in the autographic records.

As regards service to the civil engineer in the testing of materials, it would seem that the compression of a small cylinder of metal in the impact testing machine under consideration would be a useful and interesting addition to the pro-

cesses of a testing laboratory, but, at the same time, of quite limited scope. The use of the proposed brief relation

$$R = \frac{A\,M\,V}{T}$$

for the maximum pressure bringing into play, as it does, the total time of shortening and dispensing with the drawing of the "impact curve," implies that the experimenter, in selecting a proper value for the coefficient A, must make use of some acquaintance with the general characteristics of that curve, for the metal under test, as obtained previously with Lieutenant Dunn's complete apparatus. Hence, in dealing with a metal, or brand of metal, for the first time, the more elaborate apparatus would be needed, after all, and the impact curve found and interpreted, before the maximum pressure could be found.

It would seem as if a photographic device of the kind used by Lieutenant Dunn would be found more accurate in the production of autographic stress-strain diagrams below the elastic limit, in the use of the ordinary static testing machine, than those heretofore employed for this purpose (such as Professor Gray's, for example), where the magnifying of the change of length of the specimen is brought about by mechanical means. In a photographic apparatus, the Bauschinger rollers and mirrors could be used, each throwing its own beam of light on a cylinder, while the rotation of this cylinder, carrying the sensitive film or paper, could be made to keep pace with the travel of the poise; the motion of the spot of light on the paper being parallel to the axis of the cylinder.

As regards the phrase "impulsive force," in the first part of Lieutenant Dunn's paper, it may be well to call attention to the fact that recent writers on applied mechanics do not make use of the term, unless in disapproval, and treat the duration of contact of two bodies during impact as composed of an infinite number of infinitesimal elements of time, exactly as longer periods of time in other motions are considered; so that it seems a little out of place to speak of the "usual" classification of forces into "impulsive," etc.

It seems to the writer that in some of Lieutenant Dunn's

diagrams the expression "velocities after impact" would better be replaced by "velocities after the instant of first contact." As to the foot-note on p. 341, the algebraic work there given might, perhaps, have been dispensed with, and the simple statement made that the ellipse (or circle, if the scale be properly selected) is the well-known "distance-velocity" curve for a harmonic motion, where the retarding force is proportional to the displacement, or distance from the midpoint of the amplitude; and that the parabola performs the same office for the case of a constant retarding force.

The application of Lieutenant Dunn's apparatus to the ordinary impact testing machine would doubtless lead to interesting comparisons between results obtained with different sizes of "anvil" and different designs of support of the latter; in transverse tests of cast-iron bars, for instance.

MR. JAMES CHRISTIE:—The ingenious device of Lieutenant Dunn, for measuring and recording the effect of an impulsive force, is an example of a highly sensitive and delicate mechanism for registering those rapid and minute deformations in material, that could not be obtained with any degree of accuracy by less precise methods.

The extreme tenderness of the apparatus might seem to imply that its place is in a philosophical laboratory, where results determined from carefully prepared specimens are required with the highest possible precision. There would seem to be no reason, however, why the instrument in a modified form could not be very useful in the laboratory of the shops as a valuable adjunct for studying the physical properties of materials. We have very little data on the effects of impactive forces and of vibrations, for the reason that a correct record of such tests has been difficult to obtain, notwithstanding the acknowledged utility of tests of this kind. As such experiments have usually been of a crude and indeterminate character, owing to the imperfection of the recording mechanism, we are still lacking in experimental knowledge of the effect of dynamic action.

Although our literature is replete with the records of tests derived from static forces, we are still asking what are the

stress intensities and deflections, or other deformations, resulting from the impact of moving bodies of known mass and velocity? How are the strains localized or distributed throughout the body impinged upon? What are the extent and character of the stresses resulting from vibration? When do vibrations acquire such intensity as sensibly to constitute fatigue of strength or elasticity? Or is there such a thing as fatigue of elasticity as suggested by Lord Kelvin many years ago? The solution of these and similar problems awaits the advent of a suitable testing machine, whose records can inspire confidence.

This is a fruitful field of work for the aspiring youth of the technical schools, when searching for fresh fields and pastures new, and one from which rich harvests of knowledge may be garnered.

LIEUTENANT DUNN:—The writer is under many obligations to the Franklin Institute for its reception and treatment of this paper, and to the participants in the above discussion for their valuable criticisms and suggestions.

In all departments of scientific research we observe a constant addition of new and a continued subdivision of old specialties. The consciousness that his work is in a virgin field is a wonderful stimulus not entirely free from danger to the investigator. There is a critical stage in the rise of enthusiasm, after which a judgment, previously sound, becomes clouded and the specialty develops into an emancipated hobby.

During the development and use of the apparatus described, the writer had in view only the military interests in impact. The possible utility of his work to other branches of the engineering profession was an after-thought. A discussion was sought for two reasons:

(1) To determine, through the crystallized opinions of abler minds, whether the writer had become the victim of his own enthusiasm.

(2) Because the engineering profession must acquire an active interest if the great amount of necessary laboratory work is to be accomplished.

In addition to the above comments, many encouraging letters have been received from eminent engineers who, from lack of time, have not been able to join the published discussion.

Granting the creation of an active interest in the profession, it will not be difficult to arrange for a continuation of the work. The apparatus is not a costly one, and the possible results affect so many important interests, that it would be eminently proper for the general Government to bear the expense of a commission of experts, appointed to continue the investigation. The combined influence of a few eminent engineers could readily secure the necessary appropriation from the Congress.

Some of the points raised in the discussion require further notice. Through space limitation, the foundation for anvil and other important details were omitted from the published paper. Any appreciable deformation of the surface on which the specimen rests would, of course, vitiate the test. For the experiments described, a steel anvil, 10 inches in diameter and 12 inches long, was embedded in a mass of concrete, 4 by 2 feet, by 6 feet in depth, filling a hole of corresponding dimensions in dry earth.

The writer does not agree to Professor Johnson's limitation of the apparatus to plastic materials. The stresses developed by the blow can be distributed over a comparatively large anvil surface, and, with a degree of hardness in a massive anvil superior to that of the specimen, all danger of the "fatal pitfall" will be avoided. A block of Harveyized nickel-steel should not be affected by the stresses required to deform and rupture cast iron specimens. It is reassuring, also, to know that the extremely sensitive little mirror can be made to tell us whether any appreciable deflection of the upper surface of anvil is produced.

The reasons calling for an increase in our knowledge of the action of structural materials under rapidly applied stresses are stated very forcibly by Mr. Gibbs.

Prof. Church will see, by referring to the last two paragraphs, page 41, that it is not proposed to use the formula

$$R = \frac{A\,M\,V}{T}$$

in testing a new material. The construction of tables to give values of A, as a function of T, and possibly of V, for structural materials, is the laboratory work referred to as necessary. Even after this is done, it may be preferred, in important tests, to use the complete impact curve, which could be obtained and interpreted in less than an hour.

It is thought that a perfected system of revolving mirrors may throw some light on the profound questions propounded by Mr. Christie.

In introducing his interesting comments, Professor Thurston refers to the excellent work of Dr. Crehore and his coadjutors, and then to the writer's work as a "further development of similar methods," etc. This impression flows naturally from the priority of date of Dr. Crehore's published reports, but it is incorrect. The writer's apparatus was designed, constructed and used in 1891, about three years previous to the publication of Dr. Crehore's reports. Nothing was published concerning it, because the work was official, and it depended entirely on the Secretary of War to say when the publication should take place. Additional work was done in 1894, and the first publication* appeared in 1896.

It seems unsafe to predict, at this time, just where reliable impact data will be of practical value. It is quite safe to assume that such data will find a warm welcome in all branches of the engineering profession.

The relation of the mass of specimen to the difference between static and impact curves is important, and remains to be elucidated.

The copper specimen showed a higher dynamic resistance, because its molecules possess mass, and the conditions required a motion to be produced in them in a very short time. No matter how small the mass, the moving power must approach infinity as the time approaches zero. For a constant

* Ordnance Construction Note, No. 71.

difference in time of application of static and dynamic loads, the difference in corresponding resistances should increase with the mass.

The details of the apparatus described are susceptible of great improvement. The writer is occupied at present with a new instrument to investigate a problem of military interest, where the desired data will be far more difficult to obtain. An attempt will be made to secure a great increase in delicacy and accuracy of recording mechanism, and any improvements of this nature that may result will be available for use in the impact testing apparatus.

Mining and Metallurgical Section.

Stated Meeting, held Wednesday, November 10, 1897.

MR. BENJAMIN SMITH LYMAN, President, in the chair.

KRYOLITH—ITS MINING, PREPARATION AND UTILIZATION.

BY WILLIAM C. HENDERSON.

The mineral kryolith is the double fluoride of sodium and aluminium. Its composition is expressed by the formula, $6NaF,Al_2F_6$. It is made up, therefore, of sodium = 32·86 per cent., aluminium = 12·86 per cent., and fluorine = 54·28 per cent.; sometimes carrying sesquioxide of iron as an impurity. It crystallizes after the monoclinic system—occurs both in the crystalline and massive forms, usually in the latter. It is snow-white to smoky-dark in appearance; cleaves in three directions, showing rectangular cleavages; is brittle, with an uneven fracture; is translucent, and has a vitreous to greasy luster. It has a specific gravity of from 2·95 to 3·0, and a hardness of 2·5. It is fusible in the flame of a candle, its melting point being between 900° and 1,000° Celsius. It is soluble in sulphuric acid with the evolution of hydrofluoric acid. It is slightly soluble in water, Johnstrup giving this solubility as 1 part in 2730 at 12° C.

The earliest notice of this mineral was by Schumacher, in

1795, from a sample brought by a missionary from Greenland to Copenhagen. Here, from its resemblance to barite, it lay neglected until 1799, when Abildgaard, whose attention was attracted to it, undertook its examination, in the course of which hydrofluoric acid, hitherto known only in connection with fluorspar, presented itself, along with aluminium. A considerable residue remained unaccounted for, however, and the investigations were repeated by Klaproth, in 1800, who discovered the presence of sodium.

Its great fusibility, as well as its resemblance to snow, and still greater likeness, when wet, to ice, suggested to Abildgaard the name which he gave it—kryolith—from χρύος, frost, and λίθος, stone.

The mineral was later described by D'Andrada and Karsten.

In 1811, Giesecke, who was a member of the Danish Geological and Mineralogical Survey of Greenland, discovered in the colony of Frederikshaab, in southwest Greenland, at the place now known as Ivigtut, an immense deposit of kryolith. During the same year he shipped a considerable quantity of minerals, including kryolith, for Copenhagen; but as this was during the stormy period of the Napoleonic wars, the vessel never reached her destined port. She was captured by a French privateer, recaptured by an English frigate, and was finally taken into Leith, Scotland, where the cargo was condemned as worthless, and sold to Thomas Allan, an Edinburgh mineralogist, for £40.

The deposit of kryolith discovered by Giesecke, at Ivigtut, is the only one of commercial importance known at present, and no indications of its existence at any other locality in Greenland have been discovered. Comparatively small quantities have, however, been found at Miask, in the Ural Mountains, between Russia and Siberia, separated from the civilized world by 1,000 miles of desert. Also at the northeast base of St. Peter's dome, in the Pike's Peak region of Colorado, and lately it has been reported from the Yellowstone National Park, Wyoming.

The minerals usually associated with kryolith are quartz,

siderite (which occurs perfectly pure in beautiful crystals), galenite, sphalerite, pyrite, chalcopyrite and wolframite. These are irregularly scattered throughout the mass of kryolith in a manner most remarkable. They are, for the most part, easily separated during the operation of sorting, which takes place at the mines.

There are, besides, several minerals found only in connection with kryolith, some of which were, until recently, entirely unknown. Among these are: Pachnolite, thomsenolite (named after Thomsen, the originator of the kryolith industry), arksuktite, gearksuktite, ralstonite, prosopite, ivigtite (from Ivigtut) and hagemanite (named by Professor Silliman, after Hageman, who first analyzed it). These interesting impurities are readily separated from kryolith, in the process of manufacture, as they suffer no change under the chemical treatment by which the kryolith is decomposed. Eudialite also occurs in the Ivigtut region, this being the only locality—except one or two others—where it has been found.

Kryolith was at one time the chief source of aluminium, remaining so until superseded by bauxite. It is still used in the production of this metal, but not as a source of supply. Aluminium was first obtained from kryolith early in 1855, by Allan Dick, who fused the mineral with alternate layers of small pieces of sodium, in a magnesia-lined crucible.

The principal use for kryolith is found in the manufacture of soda and the by-products resulting therefrom. From no other known substance can soda be obtained with equal cheapness and abundance; and it is the only natural product, excepting salt, from which this commodity can be procured in quantities sufficient to supply the demands of commerce. The process by which soda is obtained from kryolith was devised by Prof. Julius Thomsen, of Copenhagen, in the year 1850. Still another use for kryolith exists in the production of kryolith glass, or hot-cast porcelain, a beautiful translucent substance, possessing great strength, first brought prominently into public notice by the Hot-Cast Porcelain Company, of Philadelphia, by whom it was made on a large scale, although the material had been in use in Bohemian and Silesian glass

works for some years previous to the commencement of the manufacture in America.

Ivigtut (an Eskimo word, meaning "a meadow") is located in latitude 61° 10′ north, and longitude 48° 10′ west, being a spot of land on the Arksuk Fiord, twenty miles from the coast line of southwest Greenland—a remote and gloomy region of the globe, inaccessible during the greater portion of the year, and barren of all commercial products, save kryolith.

The inhabitants of Ivigtut are solely the officers and men who operate the mines, all of whom come from Copenhagen. With but one or two exceptions, there are no women at Ivigtut. The settlement is in possession of a Lutheran church, and boasts among its social attractions, a bowling alley, a billiard parlor and a brewery. The food consumed by the people is almost exclusively supplied from Copenhagen, and consists chiefly of rye bread and salt meat, with fresh meat once or twice a week.

The nearest Eskimo settlement to Ivigtut is at Isua, 8½ miles distant.

As though with a view to insure the speedy discovery of this unique and most remarkable mineral occurrence, nature signally marked the spot with a giant monolith of spotless kryolith, which, carved through countless ages by glacial action, stood, a towering monument upon the buried treasure beneath. It further revealed itself by a series of graceful undulations separated by green sward. Its resemblance to snow was, indeed, so great, that one can readily appreciate the Eskimo belief that it was such, though of a special kind that would not melt.

Remote from civilization as is the location of this isolated deposit, at no other point, in Greenland, at least, could it have been more accessible for removal, no portion of the mineral being at a greater distance than 150 feet from low-water line, and its general elevation not exceeding 10 feet from high water. Its greatest length extends in a direction parallel to the sea in a line running northeast and southwest, covering a distance of about 400 feet, 100 feet of which is washed by the sea. That portion nearest, and facing the sea, descends per-

pendicularly to an unknown depth; that farthest from the water sinks at an angle of about 45° from the sea.

The width in the opposite direction, that is, southeast to northwest, is about 150 feet.

The deposit of kryolith, at Ivigtut, is owned by the Danish Government. The mining of the mineral is conducted exclusively by a Copenhagen company, by virtue of a lease held by them from the Government. By the terms of this lease, the value of every fifth cubic fathom of kryolith, mined and shipped from Greenland, falls to the Danish Treasury of State, whether the cargo be lost on voyage from Greenland or not. These kryolith mines were opened by Daniel Schmidt, in the year 1858. The first cargo of commercial note was shipped from Ivigtut to Copenhagen, in 1857, on board the bark *Christian;* and the first shipment to the United States was made in 1864, being consigned to Philadelphia. In January, 1865, a contract was completed with Handels Selskabet, of Copenhagen (operators of the mines at Ivigtut), by which the Pennsylvania Salt Manufacturing Company, of Philadelphia, became possessed of the exclusive privilege to import the mineral, from this deposit, into the continents of North and South America.

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That portion of the mine, which may more properly be termed the quarry, at present measures about 300 feet in length, 150 feet in width and 120 feet in depth. Three holes have been sunk still deeper into the mass, for the purpose of investigation. The deepest of these is now about 120 feet below the bottom level of the quarry, but even at this depth there are no indications that the lower boundary of the mineral has been approached.

During the summer season, which lasts from about April to November, about 140 men are employed in quarrying, mining, sorting and piling the kryolith. The drilling is done by hand, no steam drills being used, and the mineral is dislodged by blasting. It is carefully sorted into two grades, Nos. 1 and 2, of about 99 per cent. and 92 per cent., respectively, which are taken to the top of the mine in 2-ton cars, running on an incline railway operated by steam. The kryolith is carefully and accurately formed into piles of exactly 100 feet long,

20 feet wide and 4 feet high, containing 8,000 cubic feet, or about 37 cubic fathoms. The cubic fathom constitutes the unit used in estimating the quantity shipped, the more general practice of weighing not being adopted at Ivigtut. The weight of a cubic fathom of kryolith is 13·6 tons of 2,240 pounds. The greatest quantity of kryolith taken from the mines, in any one season, was that removed during the season just closed. It amounted to 13,000 tons, of which 10,500 tons were received at Philadelphia.

The best grade goes to Copenhagen; the second quality comes to Philadelphia.

The waste, including everything taken from the mines except the kryolith, is dumped into the sea, after a regular system, for the purpose of building wharves, and securing more reachable anchorage. This is extremely desirable, owing to the remarkably precipitous character of the coast. Just before winter sets in, a sluice is opened, and the mines are flooded with sea water. The object in this is to prevent them from becoming inoperative through an accumulation of ice and snow, which the whole of the summer's heat would not suffice to melt.

The force of men is then cut down to about seventy, whose efforts are chiefly confined to the quarrying of such of the kryolith as can be reached, allowing it to accumulate for removal the following summer.

Rails have been laid during the winter upon the ice in the quarry, and the whole operation carried on the same as in summer, except upon a much reduced scale. This, however, has not been found to be thoroughly practicable.

As soon as the general thaw takes place, steam pumps are put to work, the mines drained of water (an operation requiring about three weeks to perform), and work is again resumed in earnest.

The vessels employed in the kryolith trade are staunch seacraft, built expressly for the purpose. The Philadelphia fleet musters, just now, eight barks, having an average burden of 800 tons; while three small vessels, with an average of 300 tons burden, comprise the Copenhagen fleet. These make

two trips to the mines a year, arriving at Ivigtut, on the first trip, about April 10th, and again, on their second one, July 10th. Owing to the lack of reciprocity, these vessels usually make their outward voyages in ballast.

In producing soda from kryolith, Thomsen's method is still employed. The process briefly is as follows:

The previously dried and pulverized kryolith is intimately mixed with an equal weight of powdered limestone, and the mixture calcined at an incipient red heat, during which there is formed calcium fluoride, aluminate of soda, carbonate of soda and sodium hydrate. The calcined residue, known as "kryolith ash," is then subjected to careful leaching, yielding an insoluble residue of calcium fluoride and a solution containing the soda salts. The insoluble fluoride of calcium is purified by washing and is ready for the market. The solution containing the soda salts is conveyed to agitators and agitated in contact with carbonic acid gas. During this operation the soda becomes united with the carbonic acid, to form sodium carbonate, still, however, remaining in solution. The alumina separates out as aluminium hydroxide, which, upon being purified by washing, is either converted into alum, or sold as alumina.

The solution containing the carbonate of soda is concentrated to about 36° Beaumé, and the salt allowed to crystallize out, thus finally becoming the sal soda of commerce.

If it be desired to make the bicarbonate, this last product is exposed to an atmosphere of carbonic acid gas, of which it absorbs another equivalent, and yields its water of crystallization.

In the manufacture of aluminium, kryolith is used in the fused bath as a solvent, into which is introduced pure alumina, to the extent of about 21 per cent. of the weight of the kryolith (this being a much greater amount than it has been found possible to introduce into any other available substance). By electrolysis, the alumina is decomposed into its component parts, the oxygen uniting with the carbon, furnished by the highly-heated carbon electrodes, to form carbon monoxide, which escapes and burns at the surface of the bath to form car-

bonic acid gas, the aluminium being deposited at the bottom of the furnace.

In the production of kryolith glass, or hot-cast porcelain, 4 parts of powdered kryolith are mixed with 10 parts of silica and 1 part oxide of zinc. The whole is then fused and manufactured into ware, much after the same manner as is ordinary glass; but is unlike the latter, not only in appearance, but also in possessing great toughness and hardness, so that a plate, for instance, stamped out of this material, may be thrown down quite violently, without fear of its breaking.*

ELECTRICAL SECTION.

Stated Meeting, November 17, 1897.

Mr. C. W. Pike, President, in the chair.

RAILWAY BONDING.

By Walter E. Harrington.

Each manufacturer of rail bonds states his bond to be the best; the number of bonds now upon the market approximate closely about twenty different designs.

It is a difficult matter to determine which bond is the best adapted to your conditions. What may possibly answer under certain conditions will not answer under others. The majority of bonds are designed to make lateral contact with a hole in the web of the rail. This at once defines the necessity of good, clean, uniform surface in the hole, in order to insure good contact. While it may seem an easy matter to obtain good, clean, uniform surfaces, the facts are, that in the majority of instances, holes are not true and are full of ridges.

The writer has frequently removed bonds, where it seemed

* The author wishes to acknowledge his indebtedness to the gentlemen named below, for much of the information contained in this paper, and to thank them, also, for their kind aid in its preparation: Mr. Theodore Armstrong, President P. S. Mfg. Co.; Mr. Daniel Schmidt, who opened the mines at Ivigtut; Capt. Smith, of the kryolith bark *Calcium*; Capt. Anderson, of the kryolith bark *Serene*; Dr. J. V. Ingham, of Philadelphia; Mr. C. H. Ingraham, of Philadelphia; Mr. J. H. Lynch, of Philadelphia.

as if every precaution possible had been observed to make good contact, with barely more than 10 per cent. of contact. In some instances, the bonds could be readily pulled out of their holes.

Furthermore, rails will be either punched or drilled for bonds by the mill, and the holes will frequently become coated with rust before the rails are placed, resulting either in the necessity of using a file or reamer, making the holes larger than they should be. I do not wish to convey the impression that good contact cannot be made with bonds making connections through a hole in the web of the rail, as this can be done; but the frequent bad contacts upset one's confidence in them.

The use of the Edison-Brown amalgam, to improve the contacts of copper bonds, showed some very interesting results; used with the Crown bond, manufactured by the Washburn & Moen Manufacturing Company, the joint showed a decrease of 24 per cent. in resistance by amalgamating; whereas the Columbia bond, manufactured by the John A. Roebling's Sons Company, only showed a decrease of 5 per cent., showing conclusively that the forms of contact made by the Columbia bond is far superior to the Crown. This is substantiated by the data in attached table, which show that the Columbia bond has a resistance 53 per cent. of the Crown (neither amalgamated).

The troubles incident to making contact in a hole in the web of the rail led to the trial of the much-abused Bryan bond. This bond consists of a large number of parts, and is open to the objection that a bronze casting is used as part of the conductor. The bond, in brief, consists of two No. 0000 copper wires, clamped by bronze and iron castings, the bronze casting in contact with a corrugated copper washer, which is in contact with a freshly-made contact surface upon the face of the rail; the whole held together by a 1-inch bolt and nut, with a lock washer. This bond overcomes the radical objections inherent in the type such as the Crown, Columbia, depending upon their contact with the sides of a hole. The resistance of such a bond without the Edison-Brown alloy is very high. Compared with two Crown bonds non-amalgamated,

it shows a resistance 146 per cent. higher, but the amalgamation makes a remarkable difference; comparing it with the non-amalgamated Crown bond, makes a difference of just 42 per cent. in favor of the Bryan (when amalgamated); whereas compared with two Crown bonds, amalgamated, makes a lesser difference of 23 per cent. in favor of the Bryan bond, amalgamated, with a still further advantage of permanency.

The great objection to the Crown, Columbia, etc., type of bonds consists chiefly in the mechanical defects inherent in them. The vibration of the rail, with the play of the rail joint, results in a continual stress upon the small area of the contact, followed with the final loosening of the bond.

The writer has removed bonds of the above types which had been in service only a few years, and that had become loose, and the continual movement had worn the bond approximately ⅛-inch smaller in diameter in places. The Bryan bond and those types which are flexible, particularly the Edison-Brown type, are free from such mechanical defects.

While it was not the purpose of the writer to make the tests herein outlined to demonstrate the virtues of the Edison-Brown, still the results were so pronounced that especial stress is laid upon them, particularly since practical experience has demonstrated their permanency.

It will be noticed that the plastic cork type of Edison-Brown bond gave the lowest resistance of any of the bonds tested.

Conclusions:

(1) The Edison-Brown plastic cork bond gives the best results.

(2) The Standard bond, under fish-plate, is excellent, but is difficult to place.

(3) The Bryan bond is the best round fish-plate type of bond, both electrically and mechanically, provided however, that the bond is thoroughly amalgamated with the Edison-Brown alloys.

(4) The Crown and Columbia types of bonds would not be so objectionable if they were stranded, and the strands protected from electrolysis.

(5) The Crown type of bond is rendered materially efficient by the use of the Edison-Brown alloys; while the Columbia type is only benefited slightly. In both instances the Columbia is the better bond.

(6) Iron-wire bonds are highly inefficient.

(7 Any method of testing wherein drop in potential is measured from the same contacts through which current flows to make measurements, lead to false readings, as the measurements include the drop in the contacts.

Kind of Bond.	Center to Center of Contacts.	Length of Bond.	Size of Contact.	B. & S. Gauge.	Number of Wires in Bond.	Ohms.	Per Cent. Res. — A / B
	Inch.	Inch.					
Joint only—no bond . .	36	—	—	—	—	.00071	—
Iron channel pin	45	48	⅞″ pin Plate 2¾″ d., 1″ hole in it	0	1	.00049	69
Bryan—Iron wire . . .	36	39	⅜″ head	0000	2	.000286	40
Crown	30	36	⅜″ head	0000	1	.000247	34
Bryan—Iron wire, amalgamated	36	39	Plate 2¾″ d., 1″ hole in it	½″	2	.000224	31
Crown, amalgamated .	30	36	⅜″ head	0000	1	.000185	26
Bryan—Copper wire . .	36	39	Plate 2¾″ d., 1″ hole in it	0000	2	.000175	24
Columbia	30	36	⅜″ head	0000	1	.000131	18
Columbia, amalgamated	30	36	⅜″ head	0000	1	.000126	17
Stranded crown	5	7	⅜″ head	0000	1	.0001	14
Plastic socket	3½	—	—	—	—	.000093	13
Bryan—Copper wire, amalgamated	36	39	Plate 2¾″ d., 1″ hole in it	0000	2	.000071	9
Plastic cork	9	—	Surface 1¼″ d.	—	—	.00006	8
Solid rail—no joint . . .	18	There	were	holes	in web	.000013	—

Tests made on Penna. Steel Co. 7-inch girder rail, No. 238.
A = Resistance of bond. B = Resistance of joint only. 11-22-'97.

On the DENSITIES of NITROGEN, OXYGEN and ARGON, and on the COMPOSITION of ATMOSPHERIC AIR.

By A. Leduc.

Translated from Comptes Rendus de l'Académie, 1896, vol. cxxiii, page 805.
By Chief Engineer Isherwood, U. S. Navy.

As the discovery of argon has modified some numerical results concerning atomic weights, molecular volumes, and, chiefly, the density of nitrogen, which I have heretofore published, I have again been led to further experiment on some gases,* particularly oxygen, the density of which according to my previous experiments, seemed to me to be a little too low, relatively to that of chemical nitrogen.

Nitrogen.—Lord Rayleigh, who had already determined the density of nitrogen prepared in different ways, has done me the honor of communicating in writing his experiments, the chief object of which was to ascertain whether the density of this gas were independent of the process of preparation. I propose to find, as exactly as possible, the density of nitrogen, prepared by the following processes that seem best adapted to furnish it in a state of purity:

(1) Decomposition of the nitrite of ammonium by heat. The gas obtained contains considerable quantities of the oxides of nitrogen and of ammoniacal gas; it is purified by a long column of copper, followed by oxide of copper raised to incandescence.

(2) Decomposition of the nitrate of ammonium by heat. The impure nitrogen protoxide thus obtained is treated as above.

(3) Decomposition of nitric oxide by incandescent copper.

(4) Decomposition of ammoniacal gas by incandescent oxide of copper; which oxide is followed by a column of

* Executed in the Physical Laboratory of the Sorbonne.

copper that has for its object the decomposition of the oxides of nitrogen produced by the preceding reactions.

In all cases, the nitrogen obtained traverses, before entering the weighing globe, a column of potassa, and another of pumice stone saturated with H_2SO_4, and a U-tube charged with phosphoric anhydride.

A vacuum is made in all parts of the apparatus, previous to the operations, in order to prevent the presence of argon.

The weights of nitrogen, at 0° and 76 cm. contained in the globe, are comprised between 2 gr. ·8467 and 2 gr. ·8474; their mean, 2 gr. ·8470, corresponds, all corrections made, to the density 0·96717* relatively to the density of air.

Oxygen.—I have previously found for the density of oxygen relatively to the density of air 1·10506. Although this number is the result of only a single series of experiments—electrolysis of a solution of potassa—I have accepted it without hesitation because it harmonizes with other results obtained up to the present time.

After the discovery of argon this number appeared to me to be a little too low, and I then prepared the oxygen by decomposing by heat the crystallized permanganate of potassa. Before entering the weighing globe, the gas passed over potassa, acidified pumice and sulphuric anhydride. The density was found to be near 1·10527.

I now prepared the oxygen by electrolysis, but instead of a short column of spongy platinum, I employed for eliminating the hydrogen a long column of oxide of copper at a dull red heat. Three very concordant experiments gave 1·10521.

Convinced by these latter experiments of the insufficiency of the spongy platinum in the preceding ones, I accept for the density of oxygen 1·10523.

Argon.—I have many times had occasion to remark that the close concordance of the numbers obtained by Lord Rayleigh and by myself for the density of atmospheric nitrogen, implied the constancy of the proportion of argon in the atmos-

*As I have remarked in previous publications, the last decimal may have an error of several units. Further, as the present number has much probability of being too great, it can, with prudence, be reduced to 0·9671.

phere. This point has recently been put beyond doubt by Mr. Schloesing, Jr.,* who has found the proportion of argon in atmospheric nitrogen to be 0·0119.

Designate by d, d' and x, the densities of chemical nitrogen, atmospheric nitrogen and argon.

We have $(d' = 0{\cdot}97203)$.

$$d' = 0{\cdot}0119\,x + (1 - 0{\cdot}0119)\,d.$$

Whence results $x = 1{\cdot}376$.

Or, relatively to hydrogen, 19·80, instead of 19·9, heretofore accepted.

Résumé.—It will be useful to fix these results by giving the weight of a liter of each of these gases at 0°, both under the pressure of a bayre (10^6 C. G. S.) and under the normal pressure of the atmosphere at Paris, as follows:

Pressure.	Oxygen.	Nitrogen.	Argon.
1 Barye	1 gr. 4100	1 gr. 2338	1 gr. 755
1 Atmosphere	1 gr. 4293	1 gr. 2507	1 gr. 780

I shall return hereafter to the atomic weights of nitrogen and oxygen.

Composition of Atmospheric Air.—I have a great many times determined the composition of dry atmospheric air deprived of carbonic acid, etc., and have found that it contained in mean $\frac{2332}{10000}$ of its weight of oxygen.

The consideration of the densities of oxygen and atmospheric nitrogen † leads to the number 232·08, which can be taken as identical with the preceding.

On the other hand, the $\frac{768}{1000}$ of atmospheric nitrogen divides proportionally to the numbers $9881 \times 0{\cdot}96717$ and $119 \times 1{\cdot}376$, which gives $\frac{756}{1000}$ for the nitrogen and $\frac{13}{1000}$ for the argon.

The centesimal composition of mean atmospheric air is consequently represented by the following table:

	Nitrogen.	Oxygen.	Argon.
By weight	75·5	23·2	1·3
By volume	78·06	21·	0·94

* *Comptes Rendus*, November 2, 1896.

† A. Leduc. *Comptes Rendus*, August 4, 1890. The employment of the number 1·10506 for the density of oxygen led me, at that time, to 232·35. The difference seems to me to be due to experimental error.

On the Theory of Lubrication and the Determination of the Thickness of the Film of Oil in Journal Bearings.

By F. L. O. Wadsworth, E.M., M.E.

Concluded from Vol. CXLIV, p. 462

SUPPLEMENT.

DETERMINATION OF THE SPECIFIC RESISTANCE AND TEMPERATURE COEFFICIENT OF OIL IN THIN FILMS.

Introductory Note.—Considering the length of time that has now elapsed since the article describing the results of the measurement of the resistance of films was written (see appended date), it has been thought best to leave it in the original form except for a few minor changes in wording or arrangement. Foot-notes have been added wherever it was thought desirable to make modifications or corrections.

Very little work seems to have been done in determining the specific resistance and temperature coefficient of the various kinds of oil. The only experiments which the writer has been able to find are those of Brooks* on the *relative* resistances of a sample of paraffine oil for various temperatures between 4·4 C. and 93·3 C.† The experiments were made on a sheet of oil 3 millimeters thick, and about 2·3 square centimeters in cross section. No further data, however, was given from which the absolute resistance could be calculated, nor was it stated what particular kind of paraffine oil was used.

In the experiments recorded below, which have been undertaken as preliminary to the determination of the thickness of oil in journal bearings, the oil used was the best quality of commercial sperm oil, in which zinc had been placed for over a year in order to free it from any acid which it might contain. In addition to the determination of the absolute specific resistance and temperature coefficient, another object of these experiments was to determine whether there was any variation of specific resistance with variation in the thickness of the film,‡ or with the strength of current used.

APPARATUS AND METHOD.

In order to obtain a thin, uniform film of oil of a determinate thickness, the following arrangement was used:

A pair of fine (Brown & Sharpe) surface plates, size about 4 x 6 inches, were placed one above the other, with their surfaces separated a short distance

* "Wiedemann's Electricität," Vol. II, p. 5.

† Since these experiments were made, a considerable amount of work has been done in determining the insulation resistance of various kinds of oil, particularly for the very high electromotive forces used in alternate current transmission.

‡ I did not learn of Reinhold and Rücker's results on the electrical resistance of thin soap films until some time after this work had been completed. (See also foot-note on final page.)

by pieces of thin sheet rubber or mica.* At first the capillary attraction between the plates was relied upon to keep the film of oil uniformly spread between the two adjacent surfaces, but this being found sometimes unreliable, the two plates were immersed in a sheet-iron tank filled with the oil under experiment to a height just above the surface of the under plate (see *Fig. 4*). In order to avoid any danger of air bubbles in the film of oil between the plates, the upper plate was removed before beginning each series of experiments, and the oil heated to a temperature of about 50° C. The pieces of insulating material were then placed in position and the upper plate let down upon the lower one, care being taken to make the edges of the two plates exactly

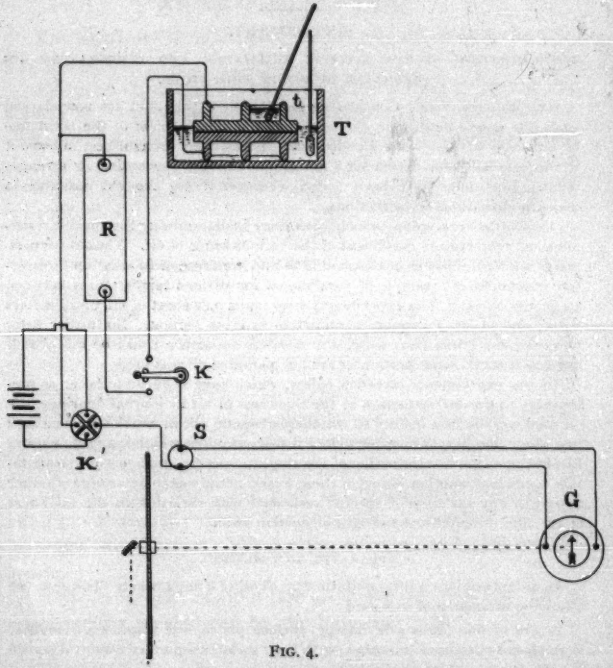

FIG. 4.

coincide. To drive out the bubbles of air which might cling to the surface of the upper plate when it was let down, the two plates were brought together with a quick, hinge-like motion. The plates and the tank of oil were then allowed to cool to the temperature of the room before beginning the measurements. The temperature was observed by means of two thermometers, one,

* A method very similar to this in principle has since been used by Threlfall for obtaining the resistance of a thin film of sulphur.—*Phil. Mag.* 38, 452 (1889).

T, immersed in the oil of the tank, the other, *W*, immersed in oil contained in the cavity of the upper surface plate. The resistance of the film of oil between the two plates was measured by comparing it with a 250,000-ohm box, by the method of deflections. The arrangement of the circuit is shown in *Fig. 4*, where

G is a Thompson galvanometer of 6,000 ohms resistance.

R is a 250,000-ohm box.

T is the tank containing the two surface plates, t_1 and t_2, arranged as before described.

K is a three-way key for changing from the circuit through *R* to the circuit through t_1 and t_2.

K' is a reverse key for reversing the current in the battery circuit.

S is a shunt in the galvanometer circuit.

Let *G* be the resistance of the galvanometer; *R* the resistance of the box; *Q* the resistance of the oil film; *B* the resistance of the battery and rest of the circuit (which may be neglected in comparison with either *Q* or *R*); S_1 and S_2 the shunts used respectively with *R* and *Q*; d_1 the deflection of the galvanometer when *R* is in circuit, and d_2 the deflection when *Q* is in circuit. Then if d_1 and d_2 are not greatly different, it has been proven

$$\frac{R+G+B}{Q+G+B} = \frac{d_2}{d_1} \cdot \frac{\dfrac{G+S_2}{S_2}}{\dfrac{G+S_1}{S_1}} \qquad (1)$$

or, since *G* is always very small in comparison with *Q*, and *B* may be neglected, we have

$$Q = (R+G)\ \frac{d_1}{d_2} \cdot \frac{S_2}{S_1} \cdot \frac{G+S_1}{G+S_2} \qquad (2)$$

The resistance *Q* is made up of two factors: one the resistance of the oil film itself; the other the resistance of the insulating pieces which are used to separate the two plates. It has been found by direct experiment that the resistance of these pieces is so high that the measured resistance *Q* may be considered as produced by the oil film alone.*

In order to determine whether variation in the current strength produced any variation in the resistance of the oil film, each film was tested with four currents, *i. e.*:

(1) That produced by one Leclanché element, E.M.F. about 1·4 volts.
(2) Two Leclanché elements in series, E.M.F. " 2·8 "
(3) Three bichromate elements in series, E.M.F. " 5·5 "
(4) Twelve cells of storage battery in series, E.M.F. " 25 "

The results are given in the tables which follow. As far as could be determined, there was no systematic difference corresponding to the differences in electromotive forces in the circuit.

When the thickness of the oil film was less than 0·01 inch some trouble was experienced from a gradual change in resistance, seemingly due to polarization of the oil film. Thus, with a film 0·01 inch in thickness, with three

* The specific resistance of sheet rubber is nearly half a million times greater than that found for the oil under test, and the resistance of paraffine is even greater.

TABLE I (Series A)

Battery.	Remarks.	Shunt $S_1 + G$ / S_1	Shunt $S_2 + G$ / S_2	Mean d_1	Mean d_2	Q_t from (2)	t	$Q_o - Q_t f(t - 20^\circ)$	
						megohms	*		δ
1 Leclanché cell	—	1/100	1	28·75	61·5	11·97	16° C.	10·53	— ·10
1 " "	Plates separated and pieces rearranged	1/100	1	29·25	62·75	11·93	16° C.	10·49	— ·14
1 " "		1/100	1	29·40	64·50	11·67	17° C.	10·58	+ ·05
1 " "	Rearranged again	1/100	1	29·50	65·25	11·59	17° C.	10·51	— ·12
1 " "		1/100	1	29·70	66·25	11·48	17°·5 C.	10·57	— ·06
1 " "	—	1/100	1	29·50	66·25	11·40	18° C.	10·66	+ ·03
2 " cells (series)	—	1/100	1/2	91·00	20 65	11·28	18° C.	10·55	— ·08
2 " " "	—	1/100	1/2	91·75	21·00	11·19	18° C.	10·47	— ·16
3 Bichromate " "	—	1/100	1/2	28·85	67·35	10·97	20° C.	10·97	+ ·34
3 " "	—	1/100	1/2	28·75	67·40	10·92	20°·5 C.	11·11	+ ·48
Storage (12 cells)	—	1/100	1/10	98 75	22·50	11·23	18°·0 C.	10·52	— ·11
" " "	Pieces rearranged again	1/100	1/10	98·50	22·50	11·21	18°·0 C.	10·51	— ·12
" " "	Taken the next day after completely rearranging apparatus	1/100	1/10	98·45	22·10	11·41	18° + C.	10·68	+ ·05
1 Leclanché cell	—	1/100	1	36·00	83·35	11·06	19° C.	10·69	+ ·06
1 " "	—	1/100	1	36·50	84·90	11·01	19° C.	10·65	+ ·02

Mean resistance at 20° 10·63 +
Probable error of mean (15) ± ·030

* Temperatures were not observed as closely as they should have been this first day.

TABLE II (Series B).

Battery.	Remarks.	Shunt $S_1 + G$ / S_1	Shunt $S_2 + G$ / S_2	Mean d_1	Mean d_2	Q_t from (2)	t	$Q_o - Q_t f(t - 20^\circ)$	
						megohms			δ
Storage battery	—	1/1000	1/10	97 75	75·75	33·03	18° + C.	30·90	—
" "	—	1/1000	1/10	98 35	7 65	32 92	18°·5 C.	31·32	—
" "	After standing some time undisturbed	1/1000	1/10	96·30	69·50	35·48	16° 5 C.	33·76	+ ·125
" "	Pressure applied to top plate	1/1000	1/10	97·60	71·75	35 00	18°·7 C.	33·51	— ·125
" "	Pressure removed	1/1000	1/10	96·25	69·85	35·28	16°·7 C.	33·77	+ ·135
" "	Pieces rearranged	1/1000	1/10	96 85	70·25	35 29	18°·7 C.	33·77	+ ·135
3 Bichromate cells (series)	—	1/1000	1/10	28·25	20·75	34·84	18°·8 C.	33·47	— ·165
3 " " "	—	1/1000	1/10	28·15	20·85	34 92	18°·8 C.	33 55	— ·085
2 Leclanché cells (series)	—	1/100	1	97·35	71 75	34·74	19° C.	33·59	— ·045
2 " " "	—	1/100	1	97 50	72·40	34·48	19° C.	33·35	— ·285
1 " cell	Plates separated and pieces rearranged.	1/100	1	36·80	27·45	34·33	19°·5 C.	33·75	+ ·115
1 " "		1/100	1	36 90	27·50	34·36	19°·5 C.	33·77	+ ·135
1 " "		1/100	1	36·90	27·55	34·28	19° 5 C.	33·70	+ ·065

Mean resistance at 20° C. (omitting first two) 33·635
Probable error of mean (11 observations) . . ± ·030

TABLE III (Series C).

Battery.	Remarks.	Shunt $S_1 + G$ / S_1	Shunt $S_2 + G$ / S_2	Mean d_1	Mean d_2	Q_t from (2)	t	$Q_o - Q_t f(t - 20^\circ)$	
3 Bichromate cells (series)	Only 3 pieces used	1/1000	1/10	28·5	111·05	6·57	22° C.	7·06	+ ·20
3 " " "		1/1000	1/10	28·35	111·75	6 50	22° C.	6·98	+ ·12
3 " " "	Pieces readjust'd end for end	1/1000	1/10	28·45	115 50	6·31	22° C.	6·78	— ·08
2 Leclanché cells (series)	—	1/100	1/10	99·70	40·50	6·31	22° C.	6·78	— ·08
1 " cell	—	1/100	1	39·75	161·50	6·31	22°·5 C.	6·90	+ ·04
1 " "	Fourth piece placed under plate	1/100	1	39·75	166·00	6·12	23°·0 C	6·82	— ·04
1 " "	Pressure applied to top plate	1/100	1/10	39·75	16·85	6·04	23°·0 C.	6·73	— ·13
1 " "	—	1/100	1/10	39·75	17·45	5·84	23°·5 C.	6·64	— ·22
1 " "	After standing 12 hours	1/100	1/10	43·15	18·00	6·14	22°·0 C.	6·60	— ·26
1 " "	Pieces rearranged	1/100	1/10	43·40	18·00	6·17	22°·5 C.	6·75	— ·11
1 " "	—	1/100	1/10	43·40	18 05	6 17	22°·5 C.	6 75	— ·11
1 " "	After standing 6 hours more	1/100	1/10	44·50	14·80	7·70	17°·8 C.	7·16	+ ·30

1	"	"	hours	1/100	1/10	43·15	18·00	6·14	22°·0 C.	6·60	— ·26
1	"	"	Pieces rearranged	1/100	1/10	43·40	18·00	6·17	22°·5 C.	6·75	— ·11
1	"	"	—	1/100	1/10	43·40	18·05	6·17	22°·5 C.	6·75	— ·11
1	"	"	After standing 6 hours more	1/100	1/10	44·50	14·80	7·70	17°·8 C.	7·16	+ ·30
1	"	"	Pieces rearranged	1/100	1/10	44·50	14·85	7·68	17°·8 C.	7·14	+ ·28
1	"	"	—	1/100	1	44·00	150·00	7·51	17°·9 C.	7·00	+ ·14
1	"	"	Heated to temp about 40° C.	1/100	1/10	43·70	22·25	5·02	25°·0 C. (?)	— ?	

Mean resistance at 20° C. 6·86 +
Probable error of mean (14) ± ·032

TABLE IV (Series D).

Battery.	Remarks.	Shunt $\frac{S_1 + G}{S_1}$	Shunt $\frac{S_2 + G}{S_2}$	Mean d_1	Mean d_2	Q_t from (2)	t	$Q_o - Q_t f(t - 20°)$
								δ
3 Bichromate cells (series)	Three pieces only used	1/100	1/10	27·80	154·00	4·62	20° C.	4·62 — ·36
3 " " "	Plates separated and pieces re-adjusted	1/100	1/10	27·75	148·50	4·78	19° 9 C.	4·76 — ·22
3 " " "	Pieces readjust'd and piece No. 4 added	1/100	1/10	27·75	146·00	4·86	19° 8 C.	4·82 — ·16
3 " " "	—	1/100	1/10	27·75	143·50	4·95	19° 8 C.	4·91 — ·07
3 " " "	After standing some time	1/100	1/10	27·60	138·50	5·10	19°·5 C.	5·01 + ·03
3 " " "	Pieces readjusted	1/100	1/10	27·50	140·75	5·00	19°·5 C.	4·92 — ·06
3 " " "	After standing 12 hours undisturbed	1/100	1/10	28·05	117·50	6·00	15° 8 C.	5·20 + ·22
3 " " "	Pieces readjusted	1/100	1/10	28·15	121·50	5·93	16°·2 C.	5·21 + ·23
2 Leclanché " "	—	1/10	1/10	103·50	48·75	5·44	17°·0 C.	4·93 — ·05
2 " " "	Pieces readjusted	1/10	1/10	106·00	49·25	5·51	17°·1 C.	5·00 + ·02
1 " cell	—	1/10	1/10	45·65	20·90	5·59	17°·1 C.	5·08 + ·10
1 " "	—	1/10	1/10	45·65	21·00	5·57	17° 4 C.	5·10 + ·12
1 " "	One piece taken out and pieces readjusted	1/10	1/10	45·75	21·25	5·51	17° 4 C.	5·05 + ·07
1 " "	Pieces readjusted again	1/10	1/10	45·85	21·75	5·40	17°·6 C.	4·99 + ·01
1 " "	Pressure applied	1/100	1/10	46·10	21·75	5·48	17°·6 C.	5·06 + ·08
1 " "	Pressure removed	1/10	1/10	45·50	21·50	5·42	17°·8 C.	5·04 + ·06

Mean resistance at 20° C. 4·98
Probable error of mean (16) ± ·026

TABLE V (Series E).

Battery.	Remarks.	Shunt $\frac{S_1 + G}{G}$	Shunt $\frac{S_2 + G}{S_2}$	Mean d_1	Mean d_2	Q_t from (2)	t	$Q_o - Q_t f(t - 20°)$
						Megohms		
One Leclanché cell used throughout.		1/10	1/10	45·85	135 85	0·327	88°·5 C.	
		1/10	1/10	45·35	29 25	0·397	77°·5 C.	
		1/10	1/10	45·75	25·10	0·467	73°·25 C.	
		1/10	1/10	45·75	23·60	0·496	71°·0 C.	
		1/10	1/10	45·75	21·25	0·551	67°·0 C.	
		1/10	1/10	45·75	17·60	0·666	61°·25 C.	
		1/10	1/10	45·70	16·45	0·711	59°·0 C.	
		1/10	1/10	45·70	13·75	0·851	55°·0 C.	
		1/10	1/10	45·70	12·95	0·903	53°·25 C.	
		1/10	1/10	45·70	9·55	1·225	42°·8 C.	
		1/10	1/10	45·70	93·50	1·251	42°·0 C.	
		1/10	1/10	45·80	85·50	1·371	40°·9 C.	
		1/10	1/10	45·80	71·25	1·646	35°·9 C.	
		1/10	1/10	45·80	68·50	1·712	34°·75 C.	
		1/10	1/10	45·85	65·00	1·806	34°·60 C.	
		1/10	1/10	45·86	62·25	1·886	33°·40 C.	
		1/10	1/10	45·85	53·00	2·215	29°·20 C.	
		1/10	1/10	45·90	49·75	2·362	27°·80 C.	
		1/10	1/10	45·95	46·50	2·53	26°·45 C.	
		1/10	1/10	45·95	44·25	2·66	25°·00 C.	3·21
		1/10	1/10	45·95	42·25	2·76	24°·10 C.	3·21
		1/10	1/10	45·95	41·75	2·82	23°·50 C.	3·20
	Made after plates had been separated 48 hours	1/10	1/10	45·10	33·05	3·49	16°·8 C.	3·14
		1/10	1/10	45·10	33·00	3·50	16°·8 C.	3·15

Mean resistance at 20° 3·18 +

bichromate cells in series, and a $\frac{1}{10}$ shunt in the galvanometer circuit, successive readings at intervals of one minute gave

Deflection right—368, 367·5, 367, 366·5, 366, 365·5, 364·5, 363·5, 363, etc.
Deflection left (battery reversed)—135, 136·5; after considerable interval—137
Deflection right—369, 368·5, 368, 368·5, etc.

To prove that this was not due to any change in the battery current, R was brought into circuit. The deflection both right and left remained perfectly steady for many minutes.

As the fall was very slow (only ½ div., or less than ½ per cent. of the whole deflection in a minute), only a very small error will be committed if the deflection is taken as soon as the oscillation of the needle due to closing the key K (which, as the needle is strongly damped takes place at the end of the second or third swing, or in from twenty to thirty seconds), has ceased. It is hardly necessary to add that in determining d_1 and d_2, the usual precaution of reversing the battery current at each observation, and taking the mean of the two successive deflections (right and left) was always adopted. At frequent intervals the galvanometer circuit was also tested by reversal, to be sure that there were no errors introduced by thermal effects.

In the case ultimately under consideration (that of measuring the resistance of a film of oil between the moving surface of a shaft and the journal box), polarization would of course be prevented by a constant movement of the layer of oil.

DETERMINATION OF SPECIFIC RESISTANCE.

In order to obtain the specific resistance from the measurements of Q we must also know:

(1) The area of the conducting film. This will be, of course, the area of the plates, less the area of the supporting pieces, which was always 0·5 square inch.

(2) The thickness of the film. The thickness of the film was determined by the measurement of the thickness of the separating pieces. These pieces were measured very carefully by a Betts measuring machine, reading to 0·0001 inch. This measurement, however, might not always give the true average thickness of the film of oil for these reasons:

(*a*) Because of the compression of the pieces when in use by the weight of the upper surface plate, a compression which is increased by the preliminary heating and subsequent contraction of the oil and plates, the contraction of the oil film drawing the plates together and compressing the separating pieces in some instances by as much as ·001 inch, as determined by measurement of the pieces before and after using. To avoid this error the measurements taken were always those which were made after the pieces had been used.

(*b*) Because of inequalities in the thickness of the different pieces. The error due to this cause is very small, as care was always taken to select pieces which were originally of as nearly the same thickness as possible. The differences found on the measuring machine never amounted to more than 2 per cent., and were generally much less. Hence the average of the pieces could be taken as representing the average thickness of the oil film.

(*c*) Because of the deflection of the plates between the points of support. This deflection, although exceedingly small, cannot be considered as negligible when compared to the thickness of the very thinnest of these films, *i. e.*,

about 0·005 inch. To prevent this effect as far as possible, the supporting pieces were so placed that their distance from the center lines of the plates was

$$\frac{l}{2\sqrt{3}}$$

where l is the distance across the plate at right angles to the center lines.

(d) Because of inequalities in the surfaces themselves. Though the two surfaces are, in general, accurately plane, nevertheless, when considered in detail, they consist of a number of points which can readily be seen and distinguished by rubbing the plates together for a short time, until the points of contact become bright and polished. Between these points are shallow cavities, due to the scraping. The error due to this cause is of contrary sign to those due to (a) and (c); and its effect will be particularly considered later.

If A denotes the effective area of the oil film, a its thickness, and Q_t the measured resistance at the temperature $t°$, we have for the specific resistance (C. G. S. units) σ_t at this temperature, if A and a are expressed in inches:

$$\sigma_t = 2{\cdot}54\, Q_t \frac{A}{a} \tag{3}$$

For the specific resistance at 0°, or at any standard temperature, ρ_0, we have:

$$\sigma_0 = 254\, Q_t \frac{A}{a} f(t-t_0) \tag{4}$$

where $f(t-t_0)$ is the temperature coefficient of the oil.

To determine this function, the oil in the tank was heated to an initial temperature of about 115°C., and then, after the whole had begun to cool uniformly, a series of simultaneous readings of temperature and resistance were taken while the oil and plates were cooling. As before, two thermometers were always used, one immersed in the oil-tank, and the other placed in a cavity filled with water in the upper surface-plate. The oil was kept thoroughly stirred, and the mean of the two readings, which (except for the higher temperature, while the plates were cooling rapidly) differed by only a slight amount, taken as representing the temperature of the oil film. For convenience, these measurements were made on the thinnest oil film used (thickness, about 0·005 inch), but there is no reason to suppose that the results would have been different for any of the other films.

DIMENSIONS OF APPARATUS.

The size of the surface-plates, as measured by a Brown & Sharp vernier caliper was 4·45 by 5·95 inches. The total area of the plates was therefore 26·5 square inches. The insulating pieces were always cut of such size that their combined area was, as already stated, 0·5 square inch. The area of the oil film was therefore 26 square inches. The films tested were of four different thicknesses, as follows:

Series A.—The insulating material was sheet rubber. Three pieces were used, of the following thicknesses:

	Inch.
No. 1, Average of six measurements gave	0·01822
No. 2, " " " "	0·01790
No. 3, " " " "	0·01827
Average thickness of three pieces (= average thickness of oil film)	0·01813

Series B.—The insulating material was sheet rubber. Four pieces were used, of the following thicknesses:

	Inch.
No. 1, Mean of six settings gave	0·0601
No. 2, " " " "	0·0613
No. 3, " " " "	0·0602
No. 4, " " " "	0·0615
Average thickness of pieces (= average thickness of film)	0·0608

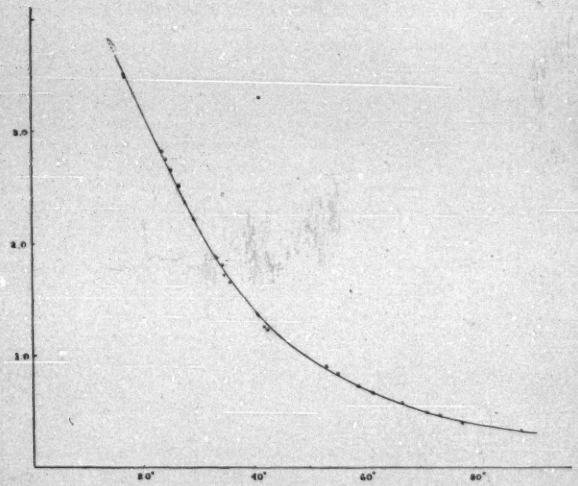

FIG. 5.

Series C.—The insulating material was paraffined paper. Four pieces were used, of the following thicknesses:

	Inch.
No. 1, Mean of six settings gave	0·01019
No. 2, " " " "	0·01017
No. 3, " " " "	0·01030
No. 4, " " " "	0·01017
Average thickness of pieces (= average thickness of oil film)	0·01021

Series D.—The insulating material was paraffined paper. Four pieces were used, but unfortunately they were accidentally destroyed before they were measured on the Bett's measuring machine. They had been measured by a micrometer caliper before being used, and the thickness so obtained, which was 0·0075 inch, is probably correct within 2 or 3 per cent.

Series E.—Combined observations for specific resistance and temperature coefficient. The material used in this case was paraffined paper. Four pieces were used of the following thicknesses:

	Inch.
No. 1. Mean of six settings gave	0·0046
No. 2. " " " " "	0·00403
No. 3. " " " " "	0·00467
No. 4 " " " " "	0·00461
Average thickness of pieces (= average thickness of oil film)	0·00462

The results of the measurements with these different thicknesses, and with the varying strength of battery current, are given in the following tables.

In order to reduce the observed resistances at different temperatures to a standard temperature, it is necessary to first determine the temperature coefficient from the observations of Series E. For this purpose these observations were first plotted (*Fig. 5*) and by the aid of a flexible steel strip a smooth curve was drawn, which represented most closely the experimental results. To represent this curve empirically an equation of the usual series form, *i. e.*,

$$Q_t = Q_0 [1 + A_1 (t - t_0) + A_2 (t - t_0)^2 + A_3 (t - t_0)^3] \qquad (5)$$

was chosen, three terms being judged sufficient to represent the results over the range of temperature observed (90° to 15° C.). In order to determine the values of Q_0, A_1, A_2 and A_3, the theoretically best method is to form a series of observation equations by substituting in (5) the observed values of Q_t and t, and deduce from them four normal equations by the method of Least Squares. But in this case the observed points fell so nearly on the smooth trial curve that it was judged sufficient to determine the values of these constants directly from four carefully selected points on the trial curve. The points so selected were those corresponding to the four temperatures of 20°, 30°, 50° and 80°. The temperature selected as standard for these experiments was 20°, as being about the mean temperature of all the series taken, and as therefore involving the least chance of error in the reductions of the observations to this temperature. The value of Q_0 is therefore at once determined. From inspection of the trial curve it was found to be

$$Q_{20°} = 3{\cdot}18 \text{ megohms.}$$

This value agrees almost exactly with that afterward found in reducing Series E, (see Table V).

For the other points we find

$$Q_{30°} = 3{\cdot}18\,(1 + 10\,A_1 + 100\,A_2 + 1000\,A_3)$$
$$Q_{50°} = 3{\cdot}18\,(1 + 30\,A_1 + 900\,A_2 + 27000\,A_3)$$
$$Q_{80°} = 3{\cdot}18\,(1 + 60\,A_1 + 3600\,A_2 + 216000\,A_3)$$

The values of A_1, A_2 and A_3, determined from these equations are, respectively :

$$A_1 = -0{\cdot}038$$
$$A_2 = +0{\cdot}00061$$
$$A_3 = -0{\cdot}0000037$$

Equation (5) thus becomes

$$Q_t = 3{\cdot}18\,[1 - 0{\cdot}038\,(t - 20°) + 0{\cdot}00061\,(t - 20°)^2 - 0{\cdot}0000037\,(t - 20°)^3] \qquad (6)$$

The curve represented by this equation between $t = 15°$ and $t = 90°$ C. is plotted in *Fig. 5*. By inspection it will be seen that it represents the results of experiment very well ; probably almost if not quite as well as it would had

the values A_1, A_2, A_3 and Q_0 all been determined by the theoretically more precise, but far more laborious process of Least Squares. Indeed in this case the amount of labor involved (as in many others where the Least Square process is commonly employed), would have been vastly disproportionate to the results achieved, and was therefore unwarranted by the accuracy of the observations themselves.

Between the points $t = 15°$ and $t = 25°$ (between which all the observations of the first four series lie) the curve corresponds almost exactly to a straight line, and can, therefore, be represented by a simpler expression of the form,

$$Q_0 = Q_0 (1 - \beta t) \qquad (7)$$

The mean value of β between these limits, as determined from the tangent to the curve at the point $t = 20°$, is

$$\beta = 0{\cdot}0343$$

The temperature coefficient of the oil is represented by the expression in the parenthesis of (6), or

$$f(t - 20°) = 1 - 0{\cdot}038\,(t - 20°) + 0{\cdot}00061\,(t - 20°)^2 - 0{\cdot}0000037\,(t - 20°)^3 \quad (8$$

or between 15° and 25° by the simpler expression from (7),

$$f_1\,(t - 20°) = 1 - 0{\cdot}0343\,(t - 20°) \qquad (9)$$

By the aid of (9) the observations in the five tables have been reduced to the chosen standard temperature of 20° C., and the means taken as representing the mean resistance of the five films at 20° C. As before stated, three, and, in some cases, four sets of measurements were made in each series, with different strengths of battery current. It will also be noted from the remarks that the plates were separated and the insulating pieces readjusted several times during each set of measurements, that the conditions of experiment were varied in many other ways (such as applying and then removing pressure from the top plate, heating and cooling the plates when in position, varying the number of supporting pieces between the plates, etc.), and that each series extended over two or three days. Under these circumstances, and considering also the number of observations, it may be fairly considered, I think, that in the mean the accidental errors of experiment have been eliminated. For the same reasons the probable errors deduced from each set may be taken as fairly representing the accuracy of the results attained. None of the observations have been omitted save the first two in Series B, which were obviously considerably in error (probably sufficient time was not given the plates to cool down after the first setting, as it will be noticed that the resistance rose to a value very near the mean "after standing for some time undisturbed"), and one in series C, where the temperature was uncertain, having been taken too soon after heating. There are several that might have been rejected on Chauvenet's criterion and the apparent accuracy thereby considerably increased, but such an arbitrary treatment of the results of physical measurement, on purely mathematical grounds, and where there has been no apparent cause of suspicion registered at the time of making these particular observations, has always seemed to me a very dangerous and unwarranted proceeding.*

* I have since had no reason to change this opinion so far as reduction of one's own observations are concerned. When it is a question of combining a large number of observations by different observers, as is necessary in Coast Survey work, the case is somewhat different.

An inspection of these probable errors (see Table VI) shows, as might have been expected, that the accuracy of the determination decreases with the thickness of the film of oil. The error in the case of the thick film (Series B) is less than one-tenth of 1 per cent., while the largest error in the case of the two thin films is only one-half of 1 per cent., a degree of accuracy considerably greater than is necessary for the purpose for which these observations were originally made.

TABLE VI.

Series.	Mean Resistance 20°.	Error in Per Cent.	Thickness.	Specific Resistance at 20°.
			Inch.	Megohms per c.c.
B	33·635 ± ·030	0·0009	0·0608	36500
A	10·63 ± ·030	0·0025	0·0181 +	38700
C	6·86 ± ·032	0·0046	0·0102 +	44300
D	4·98 ± ·026	0·0051	0·0075 (?)	43800
E	3·18	about ·005 †	0·00462 —	45400

† As judged from the divergence of the observations from a smooth curve.

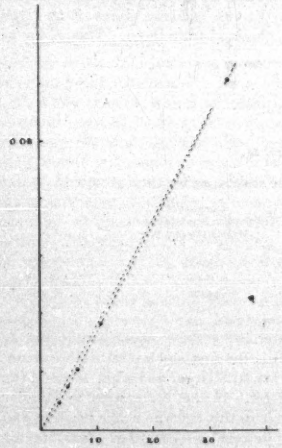

FIG. 6.

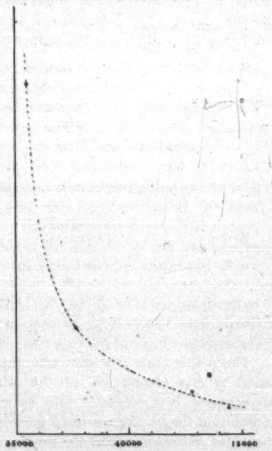

FIG. 7.

When we calculate the specific resistance from these results, we find an interesting result, viz.: that the specific resistance increases regularly as the thickness of the film decreases. This is shown in Table VI, and better in *Figs.* 6 and 7.

In *Fig.* 6 the means of the different series are plotted as a function of the thickness, and in the second the absolute specific resistance calculated from

these first results are plotted in the same way. With the exception of the one result from Series C, the points all lie on a smooth curve, which, in the first case, passes through the origin, and, in the second, appears to be asymtotic to the two axes of σ_0 and a. The variation is of too regular a character to be accidental. I had, indeed, anticipated that such a result might be obtained before beginning the experimental work, and it was for that reason that I chose to work on films as thin as I could conveniently obtain, rather than on the oil in mass. A change in specific resistance is what we might expect with decrease of thickness, because of the effect of one surface upon the other, particularly when the thickness of the film approaches the range of molecular attractions. No such limit has yet been reached here, yet it would seem that such an effect is beginning to be felt. It is possible that these results may be explained by considering that the effective thickness of the oil film is greater than the thickness of the supporting pieces on account of the cavities due to the scraping of the plates, although such an effect is directly opposed to the effect of causes (a) and (c) both of which tend to *decrease* the thickness of the film. In order to determine whether this explanation is sufficient to account for the differences I have observed, I have assumed that the effective thickness of each film is $a + x$, where x is the mean correction required to the measured thickness a, on account of the cavities in the plates. To determine x we take the two extreme values of Q_0 given in Table VI, and equate the values of σ_0 obtained from them. This gives us

$$\frac{\text{Series B.}\quad 33{\cdot}635}{0{\cdot}0608 + x} = \frac{\text{Series E.}\quad 3{\cdot}18}{0{\cdot}00462 + x}$$

Whence

$$x = 0{\cdot}00124.*$$

For the corrected thickness and specific resistance we then obtain :

Series.	Corrected Thickness. Inch.	Corrected Specific Resistance. Megohms per c.c.	δ.
B	0·06205	35750	0
A	0·01938	36200	+ 450
C	0·01145	39400	+3650
D	0·00875	37500	+1750
E	0·00587	35750	0

From this table it will be seen that while the first and last results are reconciled by this assumption, all the others are still large, and what is more, the divergence is systematic and symmetrical. If the differences were fully accounted for by the assumed correction x to the thickness, the positive and negative differences from the mean ought to have been irregularly distributed.*

The most conclusive way, however, of determining whether this explana-

* A further objection to this method of explaining the observed variation in σ, is the large value of x necessary. According to Reynolds (see p. 184 of paper already referred to) the irregularities in a well-scraped surface ought not to be greater than 0·0001 inch, and the maximum correction, therefore (supposing the hollows in the two plates to all come opposite each other !!), ought not to be more than 0·0002 inch, at the most—only one-sixth that which it is found necessary to assume.

tion is the true one or not, is to use two surfaces which have been ground together after scraping, so as to obtain two perfectly *smooth* as well as *true* surfaces. Unfortunately, I was not able to do this, because the plates were the property of the Mechanical Department. As soon as possible I intend to make a pair of plates for myself, and repeat the experiment.*

In conclusion, I wish to express my thanks to Professor Thomas for the use of his instruments and laboratory, and to Professor Robinson for the loan of the surface plates.

PHYSICAL LABORATORY, OHIO STATE UNIVERSITY,
COLUMBUS, December, 1888.

NOTES AND COMMENTS.

A NEW DEPARTURE IN THE TESTING OF METALS.

In a circular announcing the opening of testing laboratories in Boston, Mr. Albert Sauveur gives much prominence to the microscopical examination of metals. It is the first public laboratory thoroughly equipped to carry on this new and promising method of testing, and as the subject is at present receiving much attention in the metallurgical world, Mr. Sauveur's statements are of interest to the reader. He expresses himself as follows:

This new science, which has been called "microscopic metallography," has made remarkable progress in recent years, and it is confidently believed that those metallurgists who have kept in touch with its developments will admit that it is destined eventually to stand side by side with the chemical analysis of metals in importance and usefulness. The two methods of testing will complement each other. Concerning that all-important factor, the heat treatment, which contributes so powerfully to the final properties of the metal, chemical analysis can tell us nothing. This is the domain which belongs to the microscope, and in which its usefulness will become more and more appreciated.

It must be borne in mind that the physical properties of a sound piece of steel depend exclusively upon its chemical composition and upon its structure, and that the structure itself is the resultant of two factors—the composition

* When I spoke of these results to Professor Michelson, about a year after they had been obtained, he told me that he had found a similar result in the case of gold or silver films (I have forgotten which), *i. e.*, that the specific resistance of the metal, as determined from these thin films, was very much higher than the value obtained from wires or strips. This strengthened my belief still further in the reality of the observed change. Still further evidence in this direction has been afforded by the recent results of Reinhold and Rücker, on the electrical resistance of soap films. In their first work on this subject, these authors found (see Phil Trans., 188, Section A) that in soap films made from a solution containing 3 per cent. of KNO_3 in solution, the specific resistance "is the same whether the liquid be examined in bulk or in the form of a film 12 $\mu\mu$ (0·0000005) in thickness." But more recently (Proc. Royal Soc., Vol. 53, p. 394), they have found that when the salt is omitted from the solution, the specific resistance changes with change in thickness, although in this case it diminishes, *i. e.*, the electrical conductivity increases as the film grows thinner.

and the treatment which the metal has undergone. It is, therefore, of as much importance to know what the structure of the metal is as to know what its chemical composition is, in order to arrive at accurate conclusions regarding its quality, provided we can interpret the appearance of the structure intelligently. The microscope gives us a means, moreover, of ascertaining in most cases what the past heat treatment of the metal has been. The microstructure of steel is extremely sensitive to slight changes of heat treatment. To each temperature corresponds a certain structure which has its own physical properties—in other words, if a piece of steel is heated to a temperature slightly different from that of its previous treatment, it assumes a different structure, and its physical properties are consequently altered.

Attention has been called quite recently to the fact that when steel contains about 0·90 per cent. of carbon and practically no other impurities, its structure is made up of a single constituent (pearlyte), whereas with le s carbon, or when more highly carburetted, the structure is composed of two constituents (pearlyte and ferrite in the one case, pearlyte and cementite in the other). This point, which has been called the "saturation point" of steel, is an important one. The structure of the metal is here more homogeneous than it is for any other degree of carburization. It is found, however, that the presence of impurities exerts a great influence upon the position of the saturation point—that is, upon the amount of carbon necessary to saturate the steel. When, for instance, about 1 per cent. of manganese is present, 0·80 per cent. of carbon, or even less, is sufficient to produce the structural saturation. It is probably true that all impurities lower the saturation point, but in a very different degree. A steel made up of a single microscopical constituent (although a binary one) must for certain purposes present serious advantages over other grades of steel, and in the present state of our knowledge the microscope alone can tell us when the saturation point has been reached. As further experiments throw more light upon the properties (and, it is believed, superiority) of saturated steels information regarding the exact saturation point of steel of various compositions may become of great importance and be frequently sought.

It is proposed to carry on two distinct classes of microscopic tests. Class 1 will include microscopic examinations with a view of ascertaining the general character of the structure. The report will give a description of the appearance of the structure, stating the absence or presence of blowholes, slag, flaws or any other feature of an abnormal character, giving qualitative information regarding the quality of the metal and its past treatment—whether hardened, tempered or annealed; whether cast or forged; whether finished at a high or low temperature; whether hot worked or cold worked in the case of cold-drawn or cold-forged metal; whether the generally detrimental effect of cold work has been or not entirely removed by a subsequent annealing, etc.

Class 2 will give a very complete microscopical test, including the taking of a photomicrograph of the microstructure of the metal magnified to a suitable dimension (up to 1,000 diameters), and planimeter measurements of the microscopic constituents, their amounts being stated in percentages of the total area of the microscopic field, and the average size in which they occur being also given. By means of such measurements and by referring to the structure of standard specimens, information is derived regarding the quality and past

treatment of the metal of a somewhat quantitative character. If the metal was hardened, the position of the quenching temperature with regard to the critical points can be ascertained. If forged, and if the dimensions of the piece are known, the temperature at which it was finished can be stated quite closely. If the last treatment was a re-heating or an annealing, followed by slow cooling, the temperature at which such operation was performed can be inferred from the microstructure. Where pieces of iron and steel have failed by rupture or in any other way, and it is desired to test them microscopically, the piece itself should be sent; or, if too bulky, a portion from the vicinity of the fracture and including it, together with the fullest possible particulars.

Experiments of any description dealing with the heat treatment and physics of iron and steel will be undertaken to ascertain how the structure and physical properties of a certain steel are affected by a certain treatment. The position of the critical points of any steel will be determined with great accuracy, and it is firmly believed that, as the metallurgy of steel becomes a more exact science, the determination of the temperatures at which such important changes occur in the nature of the metal will become of greater moment, and will be frequently needed. Due regard to the critical points during the treatment which steel receives in the process of manufacture of the finished product would, no doubt, result in raising its quality and reliability.

TIN SCRAP.

The *Iron Age* conveys the information that there is a very large and steady export movement of tin scrap from the Atlantic coast to Europe. The amount of tinplate clippings made by the large tinware and can-making factories of the country is very considerable. Some of the more extensive works in this line put out from 50 to 100 tons of scrap tin monthly. This material, in most instances, is sold to exporters under a yearly contract. It is baled at the factory and shipped to Antwerp, from whence it is sent to a separating works in Holland, where, by a special process, the tin is recovered and made into pigs, while the steel scrap is sold for various purposes. The average value of the tinplate scrap, in bales, delivered at the dock in New York, is about $5 a ton. Some of the smaller tinware factories, which have no facilities for baling their scrap, dispose of it loose to the manufacturers of sash weights.

THE LIQUEFACTION OF FLUORINE.

In a recent impression of (London) *Nature*, a correspondent, W. J. P., has the following to say on this subject:

Fluorine was prepared for the first time in 1886 by Prof. Moissan, as a product of the electrolysis of anhydrous hydrogen fluoride contained in a platinum apparatus provided with fluorspar stoppers. The new gas was at once found to be the most active chemical substance known, many elements and organic compounds, such as arsenic, antimony, sulphur, iodine, alcohol, and turpentine, immediately and spontaneously bursting into flame when plunged into an atmosphere of fluorine. On mixing the gas with hydrogen, even in the dark, a violent detonation immediately occurs, hydrogen fluoride being

produced. The violent action of fluorine upon nearly all substances with which it is brought into contact obviously renders extremely difficult all experimental work involving the use of the free element. The great manipulative difficulties necessarily arising whilst dealing with the gas on a large scale have, however, been very happily surmounted by Prof. Moissan and Prof. Dewar, who recently described to the Chemical Society the method by which they have succeeded in liquefying fluorine, and determining the more important properties of the liquid substance (*Proc. Chem. Soc.*, November 4, 1897, p. 175). It seemed likely that the great chemical activity of fluorine might so far decrease at low temperatures as to allow of the manipulation of the material in a glass vessel cooled in liquid air; this was found to be the case.

The fluorine required in the work was prepared by the electrolysis of anhydrous hydrogen fluoride; this liquid, being a non-conductor, was made a conductor by dissolving in it potassium fluoride. The liberated fluorine was freed from hydrogen fluoride by being passed first through a platinum worm immersed in a cooling mixture of solid carbon dioxide and alcohol, and subsequently through platinum tubes containing dry sodium fluoride. The purified gas was then passed down a vertical platinum tube fused to the neck of a thin glass bulb, which served as the collector, and an exit was provided through a narrower platinum tube contained inside the first. On cooling the apparatus down to —183° in boiling oxygen whilst the fluorine is passing through, no liquefaction occurs, but, on reducing the pressure under which the oxygen is boiling, and so lowering the temperature to—185°, the fluorine condenses in the glass bulb to a very mobile yellow liquid; on removing the bulb from the cooling bath, the liquid fluorine boils vigorously. Other experiments made with boiling liquid oxygen and liquid air as refrigerating agents indicated that fluorine boils at about —187°, namely, at the boiling point of liquid argon; from this the probable critical temperature and pressure of fluorine are deduced as —120° and 40 atmospheres respectively.

At these low temperatures fluorine is without action on glass, and does not displace iodine from iodides; silicon, boron, carbon, sulphur, phosphorus and reduced iron, all of which spontaneously ignite when brought into contact with fluorine at ordinary temperatures, do not inflame if, after being cooled in liquid oxygen, they are plunged into an atmosphere of fluorine. Hydrogen gas inflames spontaneously, with considerable evolution of light and heat, when directed on to the surface of liquid fluorine at —190°; on passing fluorine on to solidified turpentine cooled by boiling liquid air, a series of explosions occurred, resulting in the destruction of the apparatus. It thus seems that the great affinity existing between hydrogen and fluorine is not overcome at —190°. A little liquid fluorine falling on the floor instantly inflames the wood. Fluorine is soluble in liquid oxygen, and on passing in the gas a white flocculent precipitate is formed, which, after filtering off, deflagrates violently as the temperature rises; it is possibly a hydrate of fluorine.

Determinations made by floating pieces of various substances in liquid fluorine indicate that its density is about 1·14, and from the invisibility of amber immersed in the liquid, the refractive index of the latter would seem to be higher than that of liquid air or oxygen. Liquid fluorine shows no magnetic phenomena when placed between the poles of a powerful electro-magnet;

it has a smaller capillarity constant than liquid oxygen, and does not solidify at —210°. It has no absorption spectrum, and its color is the same as that of the gaseous element.

ELECTRICITY ON STEAM ROADS.

In a recent address before the New York Railroad Club, Dr. Hutchinson discussed at length the subject of the application of electricity to the operation of main lines of railroad. His comments were decidedly unfavorable, and his conclusion was that the improvements made during the past fifteen years had not substantially advanced the electric motor for this branch of railway service.

While it is doubtless true that the advocates of electricity have made extravagant claims for the electric locomotive, there will be found among progressive railroad engineers few who will be willing to endorse so sweeping a condemnation of the third-rail system as that above referred to.

W.

BOOK NOTICES.

Encyclopédie des Aide-Mémoire. Librarie Gauthier-Villars et Fils. Paris: (Small 8vo. Price per volume, 2.50 francs, unbound; 3 francs, bound.)

Since our last notice of this condensed series of technical hand-books, the following additional volumes have appeared. As previously noticed, each of these volumes treats of a special subject, and is substantially complete in itself:

Henriet (*H.*), ancien Élève de l'École de Physique et de Chimie industrielles de la Ville de Paris, Chimiste à l'Observatoire de Montsouris. Les gaz de l'atmosphère.

Vallier (*E.*), Chef d'escadron d'Artillerie, Correspondant de l'Institut. Projectiles de campagne de siège et de place. Fusées.

Lefèvre (*Julien*), Professeur à l'École des Sciences et à l'École de Médecine de Nantes. Eclairage aux gaz, aux huiles, aux acides gras.

Loppé.—Accumulateurs électriques.

Lefèvre (*Julien*), Professeur à l'École des Sciences et à l'École de Médecine de Nantes. Eclairage électrique.

Urbain (*V.*), Ingénieur des Arts et Manufactures, Répétiteur à l'École Centrale. Les succédanés du chiffon en papeterie.

Fabry (*Ch.*), ancien Élève de l'École Polytechnique, Maître de conférences à la Faculté des Sciences de Marseille. Les piles électriques. W.

Stamp Milling of Gold Ores. By T. A. Rickard, Mining Engineer and Metallurgist, Fellow of the Geological Society, etc., etc. New York: The Scientific Publishing Company. Cloth, illustrated, price $2.50, 1897.

The author, whose familiarity with the subject of "Stamp Milling" is well known through his extensive contributions to current technical journals, has elaborated into the form of the present work a series of articles on the subject which originally appeared in the *Engineering and Mining Journal* and *The Mineral Industry*.

The work embodies the results of the author's practical work and observations of the methods employed in the principal gold mining districts of the world, and may be regarded as the critical expression of the views of a competent expert. It is written in plain, comprehensible style, and with the avoidance, as far as possible, of the discussion of chemical reactions and other strictly scientific data, with the view of making it of present use to those engaged in the actual work of the mill as well as to the student and teacher. In a word the book is a painstaking description of the best specimens of gold-milling practice in every part of the world. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, December 15, 1897.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, December 15, 1897.

Vice-President H. R. HEYL in the chair.

Present, 73 members and visitors.

Additions to membership since last report, 12.

In accordance with Article XV of the By-Laws, nominations for officers, managers, and committeemen were made, as follows:

For *President*	(to serve one year), ...	JOHN BIRKINBINE.
" *Vice-President*	(" three years), ...	GEORGE V. CRESSON.
" *Secretary*	(" one year), ...	WM. H. WAHL.
" *Treasurer*	(" "), ...	SAMUEL SARTAIN.
" *Auditor*	(" three years), ...	JOHN GEORGE COPE.
" "	(for the unexpired term of J. H. Cooper, deceased), ...	WM. H. GREENE.

For *Managers* (to serve three years).

GEORGE H. FRAZIER,	ALEX. KRUMBHAAR,
ALFRED C. HARRISON,	C. HARTMAN KUHN,
HENRY R. HEYL,	SAMUEL M. VAUCLAIN,
HERBERT M. HOWE,	GEORGE VAUX, JR.

For the *Committee on Science and the Arts* (to serve three years).

L. I. CHENEY,	J. LOGAN FITTS,	LINO F. RONDINELLA,
JAMES CHRISTIE,	CHAS. A. HEXAMER,	A. J. ROWLAND,
LUIGI D'AURIA,	JACOB Y. MCCONNELL,	SAMUEL SARTAIN,
J. M. EMANUEL,	CLAYTON W. PIKE,	T. CARPENTER SMITH,
WM. PENN EVANS,	STACY REEVES,	THOMAS SPENCER.

Mr. Arthur Kitson, a member of the Institute, presented a communication describing an improved incandescent light of his invention. The inventor utilizes for the purpose a mantle similar to the Welsbach, and employs as the illuminant high fire-test petroleum, which is first vaporized by the heat of the flame and burned in an air-blast, giving a blue flame similar to that of the Bunsen burner. The flame produces an intense heat and a brilliant illumination of the mantle. The method is specially adapted for lighting large areas and for street lighting, and is claimed to be remarkably cheap, when compared—light for light—with other methods of lighting for similar applications.

The subject was referred, for investigation and report, to the Committee on Science and the Arts.

The Secretary's report followed, and the meeting adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held December 1, 1897.*]

MR. JAMES CHRISTIE in the chair.

Reports on the following subjects passed first reading:

Wave Motor, Lotzgesell, Philadelphia.

Process and Apparatus for Manufacturing Carburetted Water Gas, Henry C. Reed, Chicago, Ill.

Steel-Lined Aluminum Culinary Ware, Romaine C. Cole, New York.

Reports on the following subjects were adopted:

Perpetual Power with Manageable Air-Ship.—J. A. Klefler, Philadelphia.

ABSTRACT.—The inventor's object is to supply a continuous motive force for driving machinery, ships, etc., by the use of water, compressed air, or balls. The report condemns the plans proposed as impracticable. [*Sub-Committee.*—G. M. Eldridge, Chairman; J. M. Emanuel.]

Duplication of the Cube.—Charles Morrell, Chicago, Ill.

ABSTRACT.—The method submitted by Mr. Morrell purports to be an exact means of determining, by a graphical construction, the length of the edge of a cube when volume is twice that of a given cube.

A rigorous mathematical analysis of the demonstration offered by Mr. Morrell showed that the volume of the cube thus obtained differed from the value claimed for it by about + 0·003 of the true value, the percentage of error being, therefore, three-tenths of 1 per cent., and the percentage in the linear dimension about one-tenth of 1 per cent., or so small as to (probably) escape detection by ordinary means of measurement. The report concludes that "the proposed method is mathematically defective, nor is its practical value apparent in view of the fact that by the aid of tables of logarithms, or of cubes, a more accurate determination can be made in less time. It deserves to be recorded, therefore, simply as an interesting fact, that by the graphical method * * * the so-called 'duplication of the cube' can be effected with a degree of accuracy, practically speaking, no less than that characteristic of graphical methods in general. [*Sub-Committee.*—Edgar Marburg, Chairman; Edwin S. Crawley, L. F. Rondinella, Hugo Bilgram.]

Investigations with the Electric Furnace.—Henri Moissan, Paris, France.

ABSTRACT.—This report is in substance an historical *résumé* of the researches of M. Moissan in the chemistry of high temperatures, conducted with various forms of the electric furnace.

The report has been referred to the Committee on Publications for publication in full. The award of the Elliott Cresson Medal is suggested, and is now under advisement. [*Sub-Committee.*—Paul A. N. Winand, Chairman; Charles J. Reed, Harry F. Keller.]

Improvement in Tidal Powers.—Ernst Markmann, Philadelphia.

ABSTRACT.—This invention is explained to consist of a novel construction of apparatus for deriving power from tide-water, the idea being to utilize the flow of tide-water into certain basins at high tide, and back from these basins at low tide, through turbines mounted on a float. Admission and outflow of water is regulated by the interposition of a special system of gates. For the

mechanical details of this construction the reader is referred to the inventor's letters-patent filed with the report.

The complex arrangement of gates used to direct and control the water in these basins is claimed to be an important feature of the invention, but the main feature to which the attention of the investigating committee was directed is the floating turbines. On this point the report speaks as follows: "By means of the float, on which the wheels are mounted, they are kept at the lower level for the purpose of utilizing the full height of the fall, regardless of the well-known fact that the difference of level measures the working head, no matter where the turbines may run in the course of the flow, within the limit of atmospheric pressure." The conclusion is reached that the invention presents no advantages on the score of utility. [*Sub-Committee.*—Wilfred Lewis, Wm. M. Barr.]

The Phantoscope.—C. Francis Jenkins, Washington, D. C.

ABSTRACT.—This invention relates to an apparatus for projecting upon the screen a series of photographs of moving objects taken in such rapid succession that when reproduced upon the screen the scenes and movements are in effect realistic. It is the subject of letters-patent of the United States, Nos. 536,569, 560,800 and 585,593, granted to Mr. Jenkins, to which the report makes reference for numerous details of the projection apparatus.

The report sketches the progress during the past thirty years of the art of reproducing on the screen, by various attachments to the "magic lantern," of a series of photographs of moving objects taken in more or less rapid succession; but sets forth that "but little of practical value could result until flexible films were invented, by the use of which consecutive photographs of indefinite number could be made and reproduced as positives on like films, which could be automatically passed between the lenses of a projecting lantern."

Reference is made to the contributions made to this branch of applied photography by Brown (U. S. letters-patent, August, 1869), and to the researches of Messrs. Muybridge, Renaud, Marey and Anschutz (1877–1887) in their efforts to analyze and illustrate the movements of man and animals, and a brief description of the methods employed by these investigators for making rapid, consecutive photographs is given.

The report then proceeds to consider Mr. Jenkins' contributions to this subject (commenced about 1890). These comprise the various instruments that are needed, first, to take photographs in rapid succession on a moving ribbon or flexible negative film, for making positives therefrom, and two forms of the so called phantoscope, or apparatus employed to project the series of pictures upon the screen in very rapid succession, and with realistic effect.

These devices are highly refined, and display much ingenuity in the means employed in achieving the desired effect of projecting the series of pictures on the screen in extremely rapid succession, and with the practical suppression of the flickering that constituted a serious objection to previous efforts in this direction. The details, however, could not be made intelligible without the aid of illustrations, for which reason the reader is referred to the report itself and documents filed therewith. The award of the Elliott Cresson Medal to the inventor is suggested, and is now under advisement. [*Sub-Committee.*—H. R. Heyl, Chairman; John Carbutt, Geo. A. Hoadley.]

SECTIONS.

MINING AND METALLURGICAL SECTION.—*Stated Meeting*, December 8, at 8 P.M., Mr. Benj. Smith Lyman, President, in the chair.

Paper of the evening: "Fatigue of Metal in Iron and Steel Castings," Mr. H. F. J. Porter, Bethlehem Iron Company, South Bethlehem, Pa. (Discussion.) Referred to the Committee on Publications.

Nominations for officers for the year 1898 were made.

ELECTRICAL SECTION.—*Special Meeting*, December 14, 8 P.M., Mr. Clayton W. Pike, President, in the chair.

Papers of the evening: "Speed Government in Water-Powers," Mark A. Replogle; "Transmission of Power by Constant Current in Practice," Mr. Paul A. N. Winand. (Discussion.) Mr. Replogle's paper is referred for publication.

The following were elected officers of the Section for 1898: President, Mr. W. E. Harrington; Vice-Presidents, Mr. Theodore Spencer; Mr. G. U. G. Holman; Secretary, Mr. John A. Lafore; Conservator, Dr. Wm. H. Wahl.

CHEMICAL SECTION.—*Stated Meeting*, December 21, 8 P.M., Vice-President Dr. Bruno Terne in the chair.

Paper of the evening: "The Chemistry of California Petroleums," Prof. S. F. Peckham, Ann Arbor, Mich. (Read by Prof. S. P. Sadtler.) Discussion, Referred for publication.

Officers for the year 1898 were nominated.